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Sacramento District
Engineering Division

Lower San Joaquin Feasibility Study – Environmental Impact Report/ Supplemental Environmental Impacts Statement

San Joaquin County, California

Appendix B: Engineering Summary

December 2017

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ACRONYMS

ACE	Annual Chance Exceedance
ACRA	Abbreviated Cost Risk Analysis
ASTM	American Society for Testing and Materials
CFS	cubic feet per second (flow)
CM	Construction Management
CS	Central Stockton (geographical area)
CVHS	Central Valley Hydrology Study
CWWBS	Civil Works Work Breakdown Structure
DRMS	Delta Risk Management Study
DSM	Deep Soil Mixing
DWR	California Division of Water Resources
EC	Engineer Circular
ED	Engineering Division (USACE)
EO	Executive Order
ESA	Environmental Site Assessment ID
ETL	Engineer Technical Letter (USACE)
ER	Engineer Regulation
FEMA	Federal Emergency Management Agency
FLO-2D	Flood routing model simulating channel flow, unconfined overland, and street flow over complex topography
GIS	Geographic Information Systems
HEC-HMS	Hydraulic Engineering Center – Hydraulic Modeling System
HEC-RAS	Hydraulic Engineering Center – River Analysis System
HTRW	Hazardous, Toxic, Radioactive Waste
HQ	Head Quarters (USACE)
IDC	Interest During Construction
LiDAR	Light Detection and Ranging
LMA	Local Management Agency
LS, LSJ	Lower San Joaquin
LSJFS	Lower San Joaquin Feasibility Study
MCACES	Micro-Computer Aided Cost Estimating System
NAD	North American Datum
NAVD	North American Vertical Datum
NS	North Stockton (geographical area)
NSSDA	National Standards for Spatial Data Accuracy
OMRR&R	Operation and Maintenance, Repair, Replacement and Rehabilitation
PACR	Post Authorization Change Report
PCET	Parametric Cost Estimating Tool
PDT	Project Development Team
PED	Preconstruction, Engineering, and Design
RD	Reclamation District
RE	Real Estate

ACRONYMS (Cont'd)

RMSE(r)	Root Mean Square Error in r
RMSE(z)	Root Mean Square Error in z
ROW	Right of Way
RP	Recommended Plan
SEWD	Stockton East Water District
SJAFCA	San Joaquin Area Flood Control Agency
SJR	San Joaquin River
SLR	Sea Level Rise
SoP	Standard of Practice
SPK	Sacramento District (USACE)
TPCS	Total Project Cost Summary
TSP	Tentatively Selected Plan
ULDC	Urban Levee Design Criteria
UNET	one dimensional unsteady flow model for open channel flow
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
VE	Value Engineering (study)
WTP	Water Treatment Plant

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CHAPTER 1 – INTRODUCTION

1.1 Project Description and Background

Since initiating the Lower San Joaquin Feasibility Study (LSJFS), the Project Delivery Team (PDT) representatives have developed a comprehensive flood control plan for San Joaquin County. The PDT initially developed a framework based on known constraints from the varying organizations. The federal constraints centered on adhering to Corps of Engineers (Corps) study policies for a project to be authorized for federal construction funding. The goal of the California Division of Water Resources (DWR) was the completion of the study by January 2015 to meet the goal of registering the project for state bond appropriations during the same month. San Joaquin Area Flood Control Agency's (SJAFCA) goal was the continuing effort to provide safety to their community during rising floods.

While the LSJFS began as a traditional feasibility study, it was later reprogrammed under the new Corps planning modernization 3x3x3 (3^3) and as such and was placed on a shorter schedule with matching appropriations. The transition to 3^3 occurred during the winter/spring of 2012. The original study began approximately a year earlier in the fall of 2010.

1.2 Purpose and Scope

This summary provides a synopsis of the engineering analysis conducted during the feasibility work phase of the study by the engineering portion of the PDT. The objective is to summarize the designs and cost estimates completed through the final array of alternatives and recommended plan (formerly the TSP).

1.3 Sponsors

The LSJFS was initiated as a cost share agreement between SJAFCA and the Corps in February of 2009. The Central Valley Flood Protection Board represented by the California DWR signed on as a secondary non-federal sponsor in July of 2010. The local sponsor's design team was represented by Peterson Brustad, Inc.

CHAPTER 2 – GENERAL DESIGN CONSIDERATIONS

2.1 General

The goal of the engineering appendix is to provide a summary of the methods developed to reduce flood damages. The recommended flood risk reduction area is provided in Figure 1.

2.2 Datum

The North American Datum of 1983 (NAD 83) State Plane California Coordinate System Zone III (U.S. Survey Feet) was used for horizontal control. The North American Vertical Datum of 1988 (NAVD 88) was used as the vertical datum.

2.3 Alignment and Segments

2.3.1 Incremental Study Segments thru Final Array

Following the preliminary screening effort, levees which qualified for the initial screening were estimated for fix-in-place construction and associated costs as small segments. Fix-in-place costs were estimated for small segments to provide flexibility during the refinement stages of alternatives analysis. These smaller segments allow the refinements to add or delete segments incrementally. The study area contains 92 miles of levee which were classified into approximately 130 segments that were on average 3,700 feet in length. The result of this segmentation is presented in Figures 2 through 5.

Segment stationing went unchanged during the various phases of the study. The packaging of the number of segments varied as segments were added or deleted depending on the formulation of the array.

2.4 Alternative Reaches

2.4.1 Geographical Study Segments

Study segments were developed geographically based on the adjacent water feature or tract name. Segments were created for Mosher Creek, Fourteen Mile Slough, the Calaveras River, the delta front levees between Mosher Creek and the Calaveras River, Mormon Channel, Stockton Diverting Canal, Smith Canal, San Joaquin River, French Camp Slough, Duck Creek, and Paradise Cut Bypass. A geographical feature would often dictate where a segment would begin or end. These geographical features which were used as natural starting and stopping locations were highways, levee embankments, water features, embankments, etc. See 2.3.1 for additional information, and map Figures 2 through 5 for individual segments.

2.4.2 Initial Alternatives

Lists of measures were created by the PDT during the planning charette of January 2013 to use in the formulation of alternative plans. A measure is a feature or an activity that can be implemented at a specific geographic site to address one or more planning objectives. For example, a measure could be a fix for an earthen levee such as a cut-off wall or seepage berm.

The measures were categorized into structural and non-structural solutions. Seventy-three measures were identified as potential options for the study. The six criteria which were used to rank the 73 measures were meets objective, cost, environmental impacts, acceptability (by the community), completeness, and 21st century flood plain management.

The decision to consider a measure was based on its ranking among the 6 criteria used to rank the measures including a geotechnical engineering recommendation, and a decision to implement based on need. The 73 measures were reduced to 22 measures after ranking the measures based on the criteria. Measures were identified for 3 distinct geographical areas. The areas were divided into North Stockton, Central Stockton, and Reclamation District (RD) 17 (South Stockton). Six alternatives were recommended for North Stockton, five alternatives were recommended for Central Stockton, and five alternatives were recommended for RD17. The alternatives were created through a combination of flood containment using hydraulic breach scenarios plus a common sense approach to reach lengths which might terminate at highways or high ground. The Mormon Channel bypass and Paradise Cut options were recommended as incremental alternatives for further evaluation during the Value Engineering Study. The Mormon Slough bypass diverts excess flows off the Stockton Diverting Canal and the Calaveras River. Approximately 12 miles south of Stockton is a bypass called Paradise Cut. Paradise Cut is connected to the San Joaquin River with a weir which spills during high water events and diverts flood flows from the river. This study looked at the possibility of expanding Paradise Cut making it more viable at diverting water from the San Joaquin River during high water events. Tables 1, 2, and 3 in the appendix provide further details of the initial arrays. Figure 6 through 8 are provided as representative alternatives for North Stockton, Central Stockton, and RD-17 areas respectively.

2.4.3 Focused Array

Hydraulic design provided model runs of breach simulations which were performed for the initial alternatives. Some of the alternatives were modified based on their performance after a levee breach. An example of flooding containment is shown for the North Stockton area in Figure 9. The results from Figure 9 were used as a tool by the hydraulic designer to further refine alternatives.

The following summarizes a focused array used to begin identifying the recommended plan (formerly the TSP). Where it states "No Bypass" refers to an alternative which does not recommend the Mormon Channel bypass.

Alternative 1: The No-Action Alternative. Under this plan no effort is made to further reduce the risk of flooding. The areas identified in the initial alternatives are a combination of project and non-project levees which either have geometric deficiencies, height deficiencies, through and under seepage issues, landside stability, or erosion issues.

Alternative 2A – Fix-in-Place, No Bypass: Alternative 2A is a combination of North Stockton Alternative F, Central Stockton Alternative D, and RD17 Alternative E.

Table A. Description of Implementing Alternative 2A (Figure 11)

Initial Alternative Features	Specific Features:
NS-F, CS-D, RD-17-E	Smith Canal, Mosher Slough and 14 Mile Slough Closure Structures.
Description: Delta front north and south, and Calaveras River. Addresses the right bank of the Calaveras River and the delta front as flooding sources. This alternative includes closure structures across Mosher Slough and Fourteen Mile Slough. Additionally the Calaveras River, Stockton Diverting Canal, San Joaquin River (SJR), French Camp Slough and Duck Creek are identified as flooding sources which includes the Smith Canal closure structure. The north portion of the SJR of RD-17 with a tieback levee and levee extension address the San Joaquin River and French Camp Slough as flooding sources.	

Alternative 2A is shown in Figure 11 for reference. A further evolution of Alternative 2A provides for levee improvements connecting the existing Delta Front levees to the railroad tracks along the north bank of Mosher Slough. Figure 11 does not show the Mosher Slough levee as part of the alternative which was included later.

Alternative 2B – Fix-in-Place, No Bypass: Alternative 2B is a combination of North Stockton Alternative B, Central Stockton Alternatives B and C, and RD-17 Alternative E.

Table B. Description of Implementing Alternative 2B (Figure 12)

Initial Alternative Features	Specific Features:
NS-B, CS-B, CS-C, RD-17-E	Smith Canal, Mosher Slough and 14 Mile Slough Closure Structures.
Description: Delta front north and south, Calaveras River and SJR address the delta and tidal portion of the Calaveras River as flooding sources. The alternative includes closure structures across Mosher Slough, Smith Canal, and 14 Mile Slough. For the San Joaquin River front in Central Stockton the SJR, French Camp Slough, and Duck Creek are addressed as sources of flooding. The SJR north with tieback and extension in RD-17 address the SJR and French Camp Slough as flooding sources. This alternative also extends the tieback levee to address flanking issues.	

Alternative 2B is shown in Figure 12 for reference. A further evolution of Alternative 2B provided for levee improvements connecting the existing delta front levees to the railroad tracks along the north bank of Mosher Slough. The delta front levees are denoted by the pink outlined area (erosion protection in the legend) of Figure 15. Figure 12 does not show the Mosher slough levee as part of the alternative which was included later.

Alternative 3 – Fix-in-Place with Bypass: Alternative 3 is Alternative 2B (North Stockton Alternative B, Central Stockton Alternatives B and C, and RD-17 Alternative E) with the addition of the Mormon Channel Bypass (Figure 10).

Table C. Description of Implementing Alternative 3 (Figure 13)

Initial Alternative Features	Specific Features:
NS-B, CS-B, CS-C, RD-17-E, Mormon Slough Bypass	Smith Canal, Mosher Slough, Mormon Channel bypass, and 14 Mile Slough Closure Structures.
Description: The delta and tidal portion of the Calaveras River, and SJR are addressed as flooding sources. The alternative includes a closure structure across Mosher Slough and Smith Canal. Additionally the San Joaquin River, French Camp Slough, and Duck Creek are addressed as sources of flooding. For RD-17 the north portion of the SJR with levee tieback and levee extension are included. This alternative addresses the San Joaquin River and French Camp Slough as flooding sources. The alternative includes the Mormon Channel bypass which diverts floods off the Stockton Diverting Canal and the Calaveras River.	

Alternative 3 is shown in Figure 13 for reference. A further evolution of Alternative 3 provided for levee improvements connecting the existing delta front levees to the railroad tracks along the north bank of Mosher Slough. Figure 13 does not show the Mosher Slough levee as part of the alternative which was included later. Alternative 3 evolved into Alternatives 7, 8, 9, and 10.

Further evolution of alternatives included levee raises which became Alternative 4. For more detailed information on the focused array, reference the integrated feasibility report.

2.4.4 Final Array

The final array contained combinations of the best hydraulically performing and economically justified alternatives from the focused array. A majority of the alternatives reduced residual damages to a point where additional measures couldn't be justified. The economic analysis conducted during evaluation of the focused array of alternatives evaluated if increases in levee height would be economically justified. It was determined that the NED incrementally justified levee raises also meet the DWR Urban Levee Design criteria (ULDC) for 2070 sea level conditions. All alternatives presented in the final array include incrementally justified levee raises that meet ULDC requirements in 2070.

Final array alternatives are provided in Table D. A new naming convention was used for the final array alternatives. As seen below, focused array alternative 2B plus levee raises for sea level rise is labeled LS-7b, focused array 2A plus sea level raise is labeled LS-8b. Refer to Table D for further nomenclature.

Table D. Final Array of Alternatives Information for the LSJ Study

Focused Name	Final Name	Information	Geographical Areas
2B + SLR[1] (LS-7)	LS-7b	Cut-off Wall (>75% of the fix), ~ 42 repair miles, construction footprint: ~ 364 acres	North, Central, RD-17 (Delta Front, Lower Calaveras, and San Joaquin River Levee Improvements)
2A + SLR (LS-8)	LS-8b	Cut-off Wall (>80% of the fix), ~ 53 repair miles, construction footprint: ~ 418 acres	North, Central, RD-17 (Delta Front, Lower Calaveras, Stockton Diverting Canal, and San Joaquin River Levee Improvements)
3 + SLR (LS-9)	LS-9b	Cut-off Wall (~80% of the fix), ~ 43 repair miles, construction footprint: ~ 401 acres	North, Central, RD-17 (Delta Front, Lower Calaveras, San Joaquin River Levee Improve-ments and Mormon Channel Bypass)
LS-7 w/o RD-17	LS-7a	Cut-off Wall (>85% of the fix), ~ 23 repair miles, construction footprint: ~152 acres	North and Central Stock-ton (Delta Front, Lower Calaveras, San Joaquin minus RD-17)
LS-8 w/o RD-17	LS-8a	Cut-off Wall (>90% of the fix), ~ 33 repair miles, construction footprint: ~ 214 acres	North and Central Stock-ton (Delta Front, Lower Calaveras, Stockton Diverting Canal, San Joaquin minus RD-17)
LS-9 w/o RD-17 (LS-10)	LS-9a	Cut-off Wall (>92% of the fix), ~ 33 repair miles, construction footprint: ~ 219 acres	North and Central Stock-ton (Delta Front, Lower Calaveras, San Joaquin minus RD-17, Mormon Channel Bypass)

[1] – SLR is sea level rise

As a result of the analysis required for compliance with E.O. 11988, the RD 17 alternatives were removed from further consideration in the feasibility study. This action results in a policy compliant array of the following alternatives for identification of the NED and recommended plan (formerly the TSP): Alternative 7a, Alternative 8a, and Alternative 9a.

It is understood that RD 17, with funding assistance from the State, is currently pursuing a phased strategy of levee improvements to initially increase the resistance of RD 17's levee system to under seepage and through seepage. Upon completion of that work, RD 17 intends to request USACE participation in additional improvements necessary to achieve 200-year (0.5 percent ACE) flood risk management in order to meet SB 5 requirements. Consideration of future federal participation would be subject to demonstration of a federal interest in such incremental improvements. The following summaries are provided which were used to select the recommended plan (formerly the TSP), or was information that was provided as part of the recommended plan.

2.5 Topographic Data

2.5.1 General

The primary source of topographic or terrain data for the construction of the HEC-RAS models was LiDAR data compiled by DWR under the Central Valley Floodplain Evaluation and Delineation Study (CVFED) and Delta Risk Management Study (DRMS). The minimum expected horizontal accuracy was tested to meet or exceed a 3.5-foot horizontal accuracy at 95 percent confidence level using RMSE(r) x 1.7308 as defined by the National Standards for Spatial Data Accuracy (NSSDA). Final ground surface LiDAR point elevation data in areas other than open terrain meet or exceed NSSDA standards of 0.6 feet RMSE vertical (Accuracy z = 1.2 feet at the 95% confidence level). Accuracy was tested to meet a 0.6-foot fundamental vertical accuracy at 95 percent confidence level using RMSE(z) x 1.9600 as defined by the NSSDA. The horizontal datum is NAD83 (2007) and the vertical datum the North American Vertical Datum of 1988 (NAVD88). CVFED LiDAR data was acquired in a period of several weeks between March 17, 2008 and April 4, 2008.

2.6 Hydrology

2.6.1 General

Hydrology for the San Joaquin River was based on analysis conducted by the California Department of Water Resources (DWR) and USACE for the 2002 Sacramento-San Joaquin Comprehensive Study. Hydrology for the Calaveras River and Mormon Slough was based on analysis conducted for the feasibility study between 2010 and 2014 by the local sponsors and USACE and followed procedures compatible with the California Department of Water Resources Central Valley Hydrology Study (CVHS). The following provides a summary of the hydrologic flow frequency analysis utilized as inputs to hydraulic analysis.

a. San Joaquin River. The upstream boundary for the San Joaquin River hydraulic model is the USGS stream gage San Joaquin River near Vernalis. The drainage area at the stream gage is 13,536 square miles. Records at the USGS stream gage only account for flow in the channel and do not account for overbank flow. During large floods, flow on the waterside of the right bank levee outflanks the gage before discharging into the main channel at the RD17 tieback levee. Hydrologic frequency analysis presented herein accounts for all flow passing the gage, including channel and right overbank flow.

The Sacramento-San Joaquin Comprehensive study included the entire Sacramento and San Joaquin Valleys. Thirty-day regulated flow hydrographs developed for 50% (1/2) Annual Chance Exceedance (ACE), 10% (1/10) ACE, 4% (1/25) ACE, 2% (1/50) ACE, 1% (1/100) ACE, 0.5% (1/200) ACE, and 0.2% (1/500) was used in the hydraulic analysis.

The synthetic hydrology investigated unregulated flood frequencies at mainstem and tributary locations throughout the San Joaquin Basin. The evaluation of unregulated flows is a necessary first step because a key assumption in frequency analysis is the flows reflect natural variability. The flood frequency analysis involved evaluations of long term historical records at the stream gages. The unregulated flow frequency statistics and period of record for the San Joaquin River near Vernalis were used to estimate hydrologic uncertainty for San Joaquin River reaches within the study area. The adopted statistics and period of record for the unregulated conditions are provided in Table E. A tabulation of the flood frequency estimates for flood durations between 1-day and 30-days is provided in Table F.

Table E.
Rain Flood Frequency Statistics, San Joaquin River near Vernalis, Unregulated Conditions

Flood Duration	Adopted Log Mean	Adopted Log Standard Deviation	Adopted Log Skew	Record (Years)	
				Years Evaluated	Years Used
1-Day	4.375	0.450	-0.1	1917 - 1998	82
3-Day	4.333	0.445	-0.1	1917 - 1998	82
7-Day	4.251	0.433	-0.2	1917 - 1998	82
15-Day	4.148	0.412	-0.2	1917 - 1998	82
30-Day	4.042	0.392	-0.2	1917 - 1998	82

Table F
Flood Frequency Flow Estimates, San Joaquin River near Vernalis, Unregulated Conditions

Flood Duration	Duration Average Discharge by ACE (CFS)						
	50% ACE	10% ACE	4% ACE	2% ACE	1% ACE	0.5% ACE	0.2% ACE
1-Day	24100	88400	140300	188300	244700	310400	412900
3-Day	21900	79100	124900	167000	216500	273900	363100
7-Day	18400	62500	95200	124000	156500	193000	247300
15-Day	14500	46400	69200	89000	111100	135600	171700
30-Day	11400	34300	50200	63800	78700	95200	119200

The Comp Study formulated 5 mainstem and 22 tributary storm centerings to represent the many different possibilities of aerial storm distributions and antecedent watershed conditions. For each centering, synthetic 30-day natural flow hydrographs were computed at locations throughout the Central Valley. Typically, each tributary basin was composed of several hydrographs representing inflow to headwater dams, flood control dams, and local flow. The various hydrographs were then routed to specific index points to create an unregulated hydrograph (such as San Joaquin River at Vernalis). These natural flow hydrographs represent flood time series produced by a wholly unimpaired drainage area. The unimpaired hydrographs do not reflect the influence of headwater reservoirs. The hydrographs were balanced so the average flow for all durations matched the given frequency. For example, the peak, 1-day, 3-day, 5-day, 15-day, and 30-day volumes match the family of unregulated frequency curves computed for this location.

To simulate existing conditions, a 3-step process was required to conduct simulations of reservoir regulations for each storm centering. To begin the sequence, the headwaters reservoirs upstream of the flood control reservoirs were simulated. Then, using the resulting storage time series for select headwater facilities, top of conservation storage for those flood damage reduction projects with established credit space agreements were computed. Next, using the results of the headwater simulations and the computed top of conservation series, the lower basin reservoir models were simulated, thereby completing the reservoir simulation procedure.

A regulated set of hydrographs was obtained from "hand off" points in the lower basin reservoir simulation model. These hydrographs were then used as input to a UNET unsteady flow hydraulic model of the San Joaquin River. A review of the mainstem storm centerings found that the highest peak stages along the San Joaquin River within the study area are generated by the San Joaquin River at Vernalis storm centering. Therefore, hydraulic models for only one centering were evaluated in the feasibility study.

The sensitivity of downstream peak flows to upstream levee failures was conducted to determine if it would have a significant impact the evaluation of flood risk. The model was run for three different upstream levee failure scenarios.

(1) Infinite levee with no overtopping (Infinite). This is considered the extreme high estimate because no floodplain storage is allowed. All flow is confined to the leveed channel. This describes the extreme upper limit of potential peak flow at Vernalis relative to the levee assumption.

(2) Overtopping without Failure (No Fail). This model assumed all levees would overtop but would not fail. This may not be the most likely condition because some levees would likely fail prior to overtopping (probability of poor performance indicated by the fragility curve).

(3) With levee failure condition (With Fail). This model assumed all levees would fail at the 50% fragility point. This may not be the most likely condition because not all levees would fail at the 50% fragility point during the same flood.

A comparison of peak flows for the different levee assumptions is described in Table G. The comp study models were only run for floods larger than 10% ACE.

Table G
Sensitivity of Upstream Levee Failures, San Joaquin River near Vernalis Regulated Conditions

Levee Scenario	Peak Discharge by ACE (CFS)						
	50% ACE	10% ACE	4% ACE	2% ACE	1% ACE	0.5% ACE	0.2% ACE
Infinite Levee	NA	36900	47000	58400	90800	145500	233700
No Failure	NA	35100	42300	47700	78200	144500	224100
With Failure	NA	32900	43000	50300	77300	113300	166600
Source: 2002 Sacramento-San Joaquin Comprehensive Study UNET model results.							

The peak flow of infinite height assumption was found to always be greater for a given ACE. The greatest difference between infinite height and no fail scenarios occurred at the 2% (1/50) ACE to 1% (1/100) ACE event which is probably around the floodmagnitude that most system levees are overtopped. The No-Fail and With-Fail conditions are similar for floods smaller than 1% (1/100) ACE. The No-fail is larger than the with-fail condition for floods larger than 1% (1/100) ACE. The most likely condition is probably between the no-fail and with-fail conditions.

The overtopping with no failure scenario was adopted as the most likely hydraulic condition for this study to support the risk analysis. This probability of overtopping levee failure is accounted for the FDA model using a fragility curve that assumes 100% failure probability at the levee crest.

This assumption helps make a breach probability more statistically independent rather than dependent on each other and is consistent with historical observations that the probability of a breach does not appear to be highly dependent on other breaches occurring. There is no specific guidance on how to apply overtopping assumptions to system wide risk analysis. However, the approach is consistent with the other risk and uncertainty assumptions in the FDA model. The overtopping without failure assumption is also consistent with the DWR Urban Levee Design Criteria and FEMA mapping approaches. A table of adopted regulated peak flows for this study is provided in Table H. During large floods, floodwaters are conveyed by the channel and right overbank. Therefore, hydrographs for channel and right overbanks are required for events greater than a 1% (1/100) ACE event.

Table H
Flood Frequency Flow Estimates, San Joaquin River near Vernalis Regulated Conditions

Peak Flow	Peak Discharge by ACE (CFS)						
	50% ACE	**10% ACE**	**4% ACE**	**2% ACE**	**1% ACE**	**0.5% ACE**	**0.2% ACE**
Chanel	6400	35100	42300	47700	78200	124600	165200
Right Overbank	0	0	0	0	0	20400	60500
Total	6400	35100	42300	47700	78200	144500	224100

Note: Peak channel plus right overbank flow may not equal peak total flow due to hydrograph timing.

The California Department of Water Resources is currently conducting a study of Central Valley Hydrology. The Central Valley Hydrology Study (CVHS) will provide more recent hydrologic frequency estimates throughout the study area. However, the results were not finalized at the time of this study. The draft flood frequency estimates from the CVHS study were compared to the comp study estimates and found to be similar.

Calaveras River and Mormon Slough. The upstream hydraulic model boundary for and Calaveras River and Mormon Slough is the USACE stream gage Mormon Slough at Bellota. The drainage area at the gage is 470 square miles. Flood frequency curves and a suite of 10-day hydrographs were developed for the Mormon Slough at Bellota gage. The unregulated frequency analysis was performed with PeakfqSA software which uses the Expected Moments Algorithm (EMA) and Multiple Grubbs Beck outlier test. The method is approved for use by HQ USACE. The period of record analyzed is 104 years from 1907 to 2010. Unregulated flow frequency statistics for the Mormon Slough at Bellota Gage are provided in Table 14. Unregulated discharges by frequency and duration are provided in Table J. The analysis involved routing scaled versions of four large historic flood events (reservoir inflow plus local flow hydrographs) through an HEC-ResSim reservoir routing model. Four unregulated to regulated transforms were derived and then averaged to produce a final adopted peak regulated flow frequency curve. Selected regulated hydrographs at Bellota based on the 1997 flood pattern and matching the regulated peak flow frequency curve were adopted for input into HEC-RAS model for modeling specific frequency events at Bellota. A rainfall runoff model was used to derive concurrent local flow hydrographs as internal boundary conditions in the HEC-RAS hydraulic model reaches downstream of Mormon Slough at Bellota. A table of adopted regulated peak flows for this study is provided in Table K. Although the frequency analysis utilized 104 years of record, an equivalent period of record of 52-yrs should be utilized in performance analysis to account for uncertainty in estimating the ungaged unregulated flow between New Hogan Dam and Bellota. It was reduced in half because of uncertainty about how efficiently the dam can operate to local flow conditions. This equivalent record was also adopted for multiple index points downstream of Bellota since approximately 75% or more of the total flow in the downstream levee reach is from sources upstream of Bellota.

Table I
Rain Flood Frequency Statistics, Mormon Slough at Bellota
Unregulated Conditions

Flood Duration	Adopted Log Mean	Adopted Log Standard Deviation	Adopted Log Skew	Record (Years)	
				Years Evaluated	Years Used for Statistics
1-Day	3.775	0.482	-0.810	1907 - 2010	104
3-Day	3.608	0.475	-0.753	1907 - 2010	104
7-Day	3.417	0.464	-0.666	1907 - 2010	104
15-Day	3.240	0.461	-0.671	1907 - 2010	104
30-Day	3.079	0.448	-0.668	1907 - 2010	104

Table J
Flood Frequency, Mormon Slough at Bellota
Unregulated Conditions

Flood Duration	Duration Average Discharge by ACE (CFS)						
	50% ACE	10% ACE	4% ACE	2% ACE	1% ACE	0.5% ACE	0.2% ACE
1-Day	6900	21700	29700	35300	40500	45400	51300
3-Day	4600	14600	20200	24200	28000	31600	36100
7-Day	2900	9300	13000	15800	18500	21100	24500
15-Day	2000	6100	8600	10300	12100	13800	16000
30-Day	1300	4100	5700	6800	7900	9000	10400

A rainfall runoff model was used to derive concurrent local flow hydrographs as internal boundary conditions in the HEC-RAS hydraulic model reaches downstream of Mormon Slough at Bellota. A table of adopted regulated peak flows for this study is provided in Table K.

Table K
Flood Frequency, Mormon Slough at Bellota
Regulated Conditions

	Duration Average Discharge by ACE (CFS)						
	50% ACE	10% ACE	4% ACE	2% ACE	1% ACE	0.5% ACE	0.2% ACE
Peak Flow	3520	9530	10640	12500	12500	12500	16000

b. Delta Stage-Frequency. A stage frequency analysis was conducted at four stream gages in the Sacramento-San Joaquin Delta that serve as downstream boundary conditions in the hydraulic models. The stage-frequency analysis was conducted for DWR stream gages; Old River at Clifton Court Ferry (B95340), Middle River at Bowden Highway (B95500), San Joaquin River at Ringe Pump (B95620), and Stockton Ship Channel at Burns Cutoff (B95660) . Stage-frequency estimates were developed for three future sea level conditions including 2010, 2020, and 2070. The frequency analysis is described in detail in the "Technical Memorandum, Delta Stage- Frequency Analysis for Alternative Comparisons," 9 May 2014. The stage frequency curves are provided as Tables L and M.

The stage frequency analysis was based on stage data from the period from 1953 to 2009. Historical peak stages would have been higher under existing (2010) sea level conditions. Historical stage data were adjusted to 2010 sea level conditions for use in the frequency analysis. Each data set was adjusted by increasing historical recorded elevations to 2010 conditions using the eustatic rate of sea level rise of 0.0056 ft/yr (1.7mm/yr). The rate of eustatic sea level rise was obtained from ER 1100-2-8162 and agrees with the reported value in NOAA, 2013 as the estimated rate of sea level rise over the 20th century.

Graphical stage-frequency curves were developed for each gage by plotting the historical stage records using Weibul plotting positions. Extrapolation of the stage frequency curves from 2% ACE to 0.2% ACE events was based on hydraulic model simulations of the San Joaquin River system. For larger flood events the stage-discharge relationship at each gage was based on DSM2 model results presented in the March 2002 report "Sacramento and San Joaquin River Basins Comprehensive Study, Existing Hydrodynamic Conditions in the Delta during Floods". These relationships between stage and flow at each gage site are currently the best available analysis of hydraulic conditions in the delta for extreme flood events. While suitable for economic analysis, estimates should be refined for design purposes.

Future Sea level Rise was computed following the method outlined in ER 1100-2-8162 for four scenarios. The USACE Low estimate is based on the historical rate of sea level rise. The USACE Intermediate estimate is based on Curve I and reflects an intermediate estimate of the future rate of sea level rise. The USACE Curve II estimate reflects a rate greater than the intermediate rate. The USACE high estimate is based on curve III and reflects a high estimate of the future rate of sea level rise. Estimated increases in sea level for each scenario are provided in Table N.

The Curve II rates were used to estimate future increases in sea level over the period 2010 through 2070 in the economic analysis. The Curve II rate is higher than the intermediate rate and was selected for these four locations considering the uncertainty and consequences of flooding in a highly urbanized area. As described below, stages at the boundary locations are based on a combination of flow and tide elevations and increased flow could further increase the stage at these index points. Estimates of potential inland climate change are described in the Hydrology Addendum. Future sea level rise was assumed to impact all flood frequencies the same amount because the Delta consists of a network of channels that would have similar hydraulic characteristics for higher sea level conditions.

All elevations presented in this report are provided relative to the NAVD88 vertical datum as required by ER1110-2-816. The NAVD88 datum is maintained by the National Geodetic Survey (NGS) to be free from changes related to subsidence and plate tectonics. The NAVD88 datum reflects a constant geopotential surface which is the basis for hydrodynamic and hydraulic modeling, design, and construction. Future rates of Sea Level Rise relative to the NAVD88 datum were based on the changes in Sea Level.

Elevation changes related to subsidence or plate tectonics are accounted for as a reduction in the ground elevation relative to the NAVD88 datum over time. This approach is considered to provide a more accurate assessment of the impacts of sea level rise and localized ground subsidence than application of relative sea level rise estimates derived from nearby tidal gages which do not reflect the soil conditions underlying the proposed levee locations. In addition, the hydraulic effects of stage increases are different than subsidence in hydraulic models used to derive stages throughout the study area.

The subsidence component was estimated by reviewing NAVD88 elevations for three NGS benchmarks along the San Joaquin River within the study area. All three benchmarks indicated a similar amount of vertical change from the period 1998 to 2012. It was assumed the vertical change was due to subsidence but the value is also within the expected range of uncertainty in height modernization surveys conducted by the NGS over the period. In other words the differences might not be related to subsidence. All three benchmarks indicated a subsidence rate of about 0.02 feet (0.6 mm) per year during the period 1998 to 2012. This was considered to be a high estimate of the subsidence rate and would translate to about 2 feet of subsidence over 100 years. It is also important to consider that the observed differences at the NGS benchmarks may not reflect conditions for all features throughout the study area. For example, bridges are typically set on pile foundations that may not subside at the same rate as the natural ground and that might be different than a levee. It was assumed that a reasonable medium rate would be 0.01 feet per year and a low rate would be 0.005 feet per year.

For all alternatives it was assumed the design elevation would be maintained by the sponsor through normal operation and maintenance activities over the 100 year project life. As part of Operation and Maintenance the sponsor would be required to verify the crest elevation by conducting a high order survey every 10-years to update the National Levee Database. The sponsor would be required to restore the levee profile if it was found to have subsided more than 0.5 feet. This approach to addressing subsidence related issues is described as the “Managed adaptive approach” in ETL 1100-2-1. To support PED analysis, it is recommended that the National Levee Database Survey be re-conducted and compared to confirm the assumption of levee subsidence rates in the project area. This information would then be incorporated into the settlement portion of the design, or addressed in operations and maintenance. It is estimated the crest elevation would need to be restored every 25 years for reaches that subsided at the high rate and 50 years for reaches that subsided at the medium rate. No restoration would be anticipated for reaches that subsided at the low rate.

Table L
Mean Stage estimates by Annual Chance of Exceedance, No Action Alternative
2010 Sea Level Conditions

ACE	Mean Stage (Feet-NAVD88)			
	Old River at Clifton Court Ferry (B95340)	Middle River at Borden Hwy (B95500)	Stockton Ship Channel at Burns Cutoff (B95660)	San Joaquin River at Ringe Pump (B95620)
0.002 (1/500)	13.08*	11.20*	13.01*	12.91*
0.005 (1/200)	12.12*	9.90*	12.12*	12.02*
0.010 (1/100)	11.44*	9.80*	10.10*	10.00*
0.020 (1/50)	9.95	9.57	9.90	9.80
0.040 (1/25)	9.75	9.50	9.70	9.60
0.100 (1/10)	9.35	9.10	9.30	9.20
0.200 (1/5)	8.70	8.55	8.70	8.60
0.300 (1/3)	7.70	7.80	8.15	8.05
0.500 (1/2)	7.15	7.25	7.70	7.60
0.950 (1/1.05)	6.35	6.45	6.70	6.60

* Stage estimates for events larger than 0.02 (1/50) ACE are based on hydraulic model extrapolation. While suitable for economic analysis, estimates should be refined for design purposes.

Table M
Future Mean Stage estimates by Annual Chance of Exceedance, No Action Alternative
Curve II Rate of Sea Level Change

ACE	Mean Stage (Feet-NAVD88)			
	Old River at Clifton Court Ferry (B95340)	Middle River at Borden Hwy (B95500)	Stockton Ship Channel at Burns Cutoff (B95660)	San Joaquin River at Ringe Pump (B95620)
Sea Level Conditions in Year 2020				
0.002 (1/500)	13.24*	11.36*	13.17*	13.07*
0.005 (1/200)	12.28*	10.06*	12.28*	12.18*
0.010 (1/100)	11.60*	9.96*	10.26*	10.16*
0.020 (1/50)	10.11	9.73	10.06	9.96
0.040 (1/25)	9.91	9.66	9.86	9.76
0.100 (1/10)	9.51	9.26	9.46	9.36
0.200 (1/5)	8.86	8.71	8.86	8.76
0.300 (1/3)	7.86	7.96	8.31	8.21
0.500 (1/2)	7.31	7.41	7.86	7.76
0.950 (1/1.05)	6.51	6.61	6.86	6.76
Sea Level Conditions in Year 2030				
0.002 (1/500)	13.45*	11.57*	13.38*	13.28*
0.005 (1/200)	12.49*	10.27*	12.49*	12.39*
0.010 (1/100)	11.81*	10.17*	10.47*	10.37*
0.020 (1/50)	10.32	9.94	10.27	10.17
0.040 (1/25)	10.12	9.87	10.07	9.97
0.100 (1/10)	9.72	9.47	9.67	9.57
0.200 (1/5)	9.07	8.92	9.07	8.97
0.300 (1/3)	8.07	8.17	8.52	8.42
0.500 (1/2)	7.52	7.62	8.07	7.97
0.950 (1/1.05)	6.72	6.82	7.07	6.97
Sea Level Conditions in Year 2070				
0.002 (1/500)	14.74*	12.86*	14.67*	14.57*
0.005 (1/200)	13.78*	11.56*	13.78*	13.68*
0.010 (1/100)	13.10*	11.46*	11.76*	11.66*
0.020 (1/50)	11.61	11.23	11.56	11.46
0.040 (1/25)	11.41	11.16	11.36	11.26
0.100 (1/10)	11.01	10.76	10.96	10.86
0.200 (1/5)	10.36	10.21	10.36	10.26
0.300 (1/3)	9.36	9.46	9.81	9.71
0.500 (1/2)	8.81	8.91	9.36	9.26
0.950 (1/1.05)	8.01	8.11	8.36	8.26
Sea Level Conditions in Year 2120				
0.002 (1/500)	17.38*	15.50*	17.31*	17.21*
0.005 (1/200)	16.42*	14.20*	16.42*	16.32*
0.010 (1/100)	15.74*	14.10*	14.40*	14.30*
0.020 (1/50)	14.25	13.87	14.20	14.10
0.040 (1/25)	14.05	13.80	14.00	13.90
0.100 (1/10)	13.65	13.40	13.60	13.50
0.200 (1/5)	13.00	12.85	13.00	12.90
0.300 (1/3)	12.00	12.10	12.45	12.35
0.500 (1/2)	11.45	11.55	12.00	11.90
0.950 (1/1.05)	10.65	10.75	11.00	10.90

* Stage estimates for events larger than 0.02 (1/50) ACE are based on hydraulic model extrapolation. While suitable for economic analysis, estimates should be refined for design purposes.
Future Sea Level based ER 1100-2-8162 Curve II. Low, Intermediate, and High estimates can be computed using values in Table 19.

Table N. Sea Level Rise and Ground Subsidence from 2010 Conditions

Year	Sea Level Rise from 2010 Conditions (Feet)				Potential Ground Subsidence from 2010 Conditions (Feet)		
	USACE Low (Historic)	USACE Intermediate Curve I	**Adopted Curve II**	USACE High Curve III	Low	Medium	High
2010	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00
2015	0.03	0.05	**0.07**	0.10	0.03	0.05	0.10
2020	0.06	0.10	**0.16**	0.23	0.05	0.10	0.20
2025	0.08	0.15	**0.26**	0.37	0.08	0.15	0.30
2030	0.11	0.21	**0.37**	0.53	0.10	0.20	0.40
2035	0.14	0.28	**0.49**	0.70	0.13	0.25	0.50
2040	0.17	0.34	**0.62**	0.90	0.15	0.30	0.60
2045	0.20	0.42	**0.77**	1.12	0.18	0.35	0.70
2050	0.22	0.49	**0.92**	1.35	0.20	0.40	0.80
2055	0.25	0.58	**1.09**	1.60	0.23	0.45	0.90
2060	0.28	0.66	**1.27**	1.87	0.25	0.50	1.00
2065	0.31	0.75	**1.46**	2.16	0.28	0.55	1.10
2070	0.34	0.85	**1.66**	2.47	0.30	0.60	1.20
2075	0.36	0.95	**1.87**	2.80	0.33	0.65	1.30
2080	0.39	1.05	**2.09**	3.14	0.35	0.70	1.40
2085	0.42	1.16	**2.33**	3.50	0.38	0.75	1.50
2090	0.45	1.27	**2.58**	3.89	0.40	0.80	1.60
2095	0.47	1.39	**2.84**	4.29	0.43	0.85	1.70
2100	0.50	1.51	**3.11**	4.71	0.45	0.90	1.80
2105	0.53	1.64	**3.39**	5.14	0.48	0.95	1.90
2110	0.56	1.77	**3.68**	5.60	0.50	1.00	2.00
2115	0.59	1.90	**3.99**	6.07	0.53	1.05	2.10
2120	0.61	2.04	**4.30**	6.57	0.55	1.10	2.20
Rate of Sea Level Rise based on ER 1100-2-8162.							

c. Interior Drainage. An interior drainage analysis was performed by Peterson-Brustad Incorporated (PBI) for Bear Creek, Mosher Creek, and French Camp Slough sub-basins impacting the study area. A storm centered over the urban area of Stockton was utilized for the analysis. The interior drainage analysis evaluated rainfall runoff and flood depths for 50% (1/2) ACE through 0.2% (1/500) ACE flood events. Storm events with 72-hour durations were evaluated. The analysis utilized an HEC-HMS model to compute sub basin runoff and a FLO-2D two dimensional hydraulic model to route the runoff through the study area. The analysis indicated that interior drainage was not a significant factor in estimating annualized flood damages within the study area. Therefore, interior drainage was not studied in further detail in the alternatives analysis.

The effects of sea level change are estimated to have minor impacts on interior drainage because the affected interior drainage area is currently drained by a system of detention ponds and pumps that evacuate the water to the adjacent delta sloughs. Increases in sea level are likely to result in a gradual increase in pump head and a corresponding reduction in the performance of the pumps over time. However, any increase in pump sizes necessary to maintain similar capacity are likely to be addressed by the local community as the pumps reach the end of their normal service life.

2.7 Hydraulics

2.7.1 General

The following provides a summary of the hydraulic design and evaluation of the final array of alternatives.

a. Hydraulic Models: Four separate hydraulic models, adapted from existing hydraulic models, were utilized to evaluate the final alternatives for this study. Water surface profiles for the San Joaquin River were computed using a HEC-RAS unsteady one-dimensional flow model of the San Joaquin River system. Water surface profiles for Calaveras River and Mormon Slough were computed using a HEC-RAS one dimensional unsteady flow model of the system. Levee breach simulations for the area North of French Camp Slough were conducted using the North FLO-2D model. Levee breach simulations for the area south of French Camp Slough were conducted using the south FLO-2D model.

b. Hydraulic Design Features. Hydraulic design features incorporated into the alternatives included levee raises, erosion protection, closure structures and setback levees.

c. Wind Wave Analysis: An analysis of wind wave run-up, wind wave setup, overtopping discharge, and wind wave erosion was conducted for levee reaches within the study area. The results of the wind wave analysis determined that erosion protection was necessary along the western slope of the delta front levees to keep a breach from occurring.

d. Project Performance and Flood Risk. Performance and Flood Risk were assessed using the USACE FDA model version 1.2.5a (USACE, 2010). The FDA model combines flow-frequency, stage-discharge, geotechnical fragility, and stage-damage relationships to estimate damages. Uncertainty in each relationship is incorporated by assigning uncertainty estimates and applying a Monte Carlo type approach to combine the results.

e. Potential Adverse Effects. A potential adverse hydraulic effect would be induced flooding within the system. Induced flooding could result from a project increasing the depth, duration, or frequency of flooding. The potential for induced flooding was evaluated by comparing with-project and no action plans throughout the system. Depending on the location within the project area induced flooding was determined to be either equal to the no action alternative, or was reduced compared to the induced flooding potential for the no-action alternative. It was determined that the changes were not significant and no mitigation features would be required.

Climate Change. The delta reaches of the study area are affected by changes in sea level. Project performance was estimated for both 2010 (beginning of economic analysis) and 2070 (end of economic analysis) conditions using the hydraulic model results for 2010 and 2070 sea level conditions at downstream boundary conditions.

f. California State Urban Level of Protection (ULOP). Although the California State Urban Levee of Protection is not a federal objective of the study, it is a local sponsor objective. For levees to meet the ULOP requirements they must be designed to meet the requirements in the State of California Urban Levee Design Criteria (ULDC).

The requirements for a levee to be recognized as contributing to an ULOP are defined in the May 2012 State of California report "Urban Levee Design Criteria" (DWR, 2012). The purpose of the Urban Levee Design Criteria (ULDC) is to provide engineering criteria and guidance for civil engineers to follow in meeting the requirements of California's Government Code Sections 65865.5, 65962, and 66474.5 with respect to findings that levees and floodwalls in the Sacramento-San Joaquin Valley provide protection against a flood that has a 1-in-200 chance of occurring in any given year (Annual Chance of Exceedance (ACE)), and to offer this same guidance to civil engineers working on levees and floodwalls anywhere in California (DWR, 2012).

The ULDC provides two options for determining if a levee meets the urban and urbanizing area levee system design.

- The freeboard option (option 1) requires 3 feet of freeboard above the median 0.5% (1/200) ACE flood event.
- The risk and uncertainty option (option 2) allows for a lesser amount of freeboard if a high level of assurance can be demonstrated. For assurance less than 90% the levee does not pass the ULDC criteria. For assurance between 90 and 95% the levee must have minimum of 3 feet of freeboard to pass the ULDC criteria. For assurance greater than 95% levee must have minimum of 2 feet of freeboard to pass the ULDC criteria.

Both ULDC approaches require that modeled water surface profiles assume other levees in the system can overtop, but not fail. Other urban area levees throughout the system are assumed to be at their existing elevation or 0.5% (1/200) plus 3 feet of freeboard, whichever is higher, and non-urban levees are assumed to be at their existing elevation or their authorized design profile, whichever is higher. Both ULDC approaches require that additional freeboard be provided if the wind-wave run-up from a 1.3% ACE wind event would exceed the top of levee for the 0.5% (1/200) ACE event. Both ULDC approaches also require minimum geotechnical, geometry, erosion control, vegetation, right of way, encroachment, and penetration standards, plus a number of other standards.

g. The hydraulic performance of each alternative relative to the ULOP requirements was conducted.

h. It was estimated that levee reaches in the recommended plan would meet the ULDC criteria if additional improvements to address outflanking of the existing RD17 tieback levee were made in the future. Increases in sea level to the year 2070 were considered in the evaluation. However, increases in flood flow frequency related to climate change were not considered. The State of California is currently conducting climate change studies with respect to flood flow frequency and these studies could impact this assessment. Project performance values provided in this report are based on the existing configuration of the RD17 tieback levee. Project performance values are provided for both 2010 and 2070 sea level conditions. Inland climate change was not included because of the high degree of uncertainty.

i. General Hydraulic Design: All project features were designed to meet current USACE design requirements for stability and seepage. It should be noted there is no specific design requirements for levee height. The design height of the final alternatives is based on reasonably maximizing net benefits. The determination of maximum net benefits is described in the economic appendices and the plan formulation document.

2.8 Soil Design

2.8.1 General

The geotechnical work presents the results of the geotechnical analyses and feasibility level geotechnical recommendations to address technical deficiencies in the flood risk management system protecting the Lower San Joaquin River Feasibility Study area (LSJRFS). For the geotechnical engineering evaluation of the LSJRFS area, the following tasks were performed and summarized in the report:

- review of currently available geology, geomorphology, and geotechnical information
- review of past performance and flood control system construction history/improvements
- identification of levee performance deficiencies through geotechnical analysis and engineering judgment
- probabilistic geotechnical analysis and development of levee performance curves
- seismic study of existing levees
- development of geotechnical conclusions and recommendations

2.8.2 Design Criteria

USACE standard levee design and construction criteria as established in both national (HQ) and local (District and Division) policy documents were followed during analyses and development of mitigation regarding geometry, seepage and stability, vegetation and access, fill material, bank protection, and seismicity and liquefaction.

2.8.3 Evaluation of Existing Condition

Existing conditions were initially characterized by 14 Index points representing approximately 40-miles of existing levees within the study area. These 14 index points were selected for geotechnical analysis to represent the critical surface and subsurface conditions of each planning reach in order to identify the geotechnical deficiencies of the reach. The sections were selected based on previous geotechnical analysis, past levee performance, existing levee improvements, subsurface data, laboratory test results, surface conditions, field reconnaissance, and levee geometry. As part of the Planning process additional lengths of existing levees and also potential new levee alignments were added, expanding the project study area to roughly 90 miles. All of the existing and proposed levees with-project conditions were analyzed using the 14 index points. The index point locations are shown in Figure 1 and the dominant failure mechanism is listed in Table 4 of the appendix.

Potential sources of levee distress considered in the analyses were underseepage through the levee foundation, through-seepage through the levee embankment, and instability of the landside levee slope under steady state conditions. The levees were evaluated against the above mentioned performance modes at five different water surface elevations. Using this method of selecting loading conditions, the levee performance curves would theoretically represent probability of poor performance at multiple flood frequencies.

For the results of the fragility curve, a judgment based conditional probability function was provided based on the existing and past erosion history of the levee and riverbank, maintenance, encroachments, vegetation on the levee slopes and within the levee critical area, animal burrows and other external damaging conditions. The total conditional probability of poor performance of the levee as a function of water elevation was developed by combining the probability of poor performance functions for four failure modes: underseepage, through-seepage, slope instability, and judgment.

2.8.4 Conclusions

2.8.4.1 South Stockton

The analyses performed for South Stockton indicated that the levees represented by index points LR-1, LR-2, and LR-3 in RD-17 did not meet minimum levee design criteria at various flood frequencies. Historical documentation indicates performance-related issues with seepage, slope instability, and erosion. The measures identified in this study to mitigate these performance issues, to create with-project conditions, typically included a cutoff wall and/or seepage berm.

2.8.4.2 Central Stockton

The analyses performed for Central Stockton indicated that the levees represented by index points FR-1 in RD-404, and SL-1 and SL-2 along Stockton Diverting Canal did not meet minimum levee design criteria at various flood frequencies. Segments of the RD-404 levees can be identified in Table V. in 3.1.1. The segments can be located on Figures 2 or 4. Historical documentation indicates performance-related issues with seepage and erosion along RD-404, erosion along the left bank of the Calaveras River with isolated areas of seepage, and erosion along the left bank of Stockton Diverting Canal. The measures identified in this study to mitigate these performance issues, to create with-project conditions, typically included a cutoff wall and/or seepage berm.

2.8.4.3 North Stockton

The analyses performed for North Stockton indicated that the levees represented by index points CR-1/CR-2 and D-4 along the right bank of the Calaveras River, and index point D-BS along Delta Brookside, did not meet minimum levee design criteria at various flood frequencies. Historical documentation indicates performance-related issues with settlement, seepage, erosion, and animal burrowing activity along the Delta Brookside study area, and seepage and erosion along Delta Lincoln Village study area. The Delta Brookside area is denoted by reaches CR_10_R, and segments TS_10_L thru TS_30_L in Figure 15. The Delta Lincoln Village area is denoted by reaches FS_10_R, FM_60_L, FM_40_L and FM_30_L on Figure 15. The measures identified in this study to mitigate these performance issues, to create with-project conditions, typically included a cutoff wall and/or seepage berm.

2.8.4.4 Seismic Study

The results of seismic and liquefaction evaluation indicated isolated areas throughout the study area that are capable of inducing significant deformation of the levees. Some of the levees in North Stockton are classified as frequently hydraulically loaded levees due to the tide and may be susceptible to significant deformation due to a seismic event. Most of the study area is unlikely to be capable of inducing flow failures, and significant deformation of the levees, however the Delta Lincoln Village and the levees north of Delta Brookside may be susceptible to significant deformation due to a seismic event. For seismic remediation, the measure identified includes deep-soil mixing columns that extend just beyond the extents of the levees prism.

2.8.5 Recommended Design Recommendation

With the exception of some proposed closure structures and set-back levees, the predominant project recommendation was fix-in-place of existing structures. The measure chosen to mitigate areas of poor performance was a cutoff wall and/or a seepage berm.

2.9 Civil Design

2.9.1 General

To begin estimating different alternatives for the focused array to final array, a computer based spreadsheet tool was used. The spreadsheet tool would ultimately help manage and produce preliminary estimates within the short time frame and resources the team faced under the new 3^3 planning modernization. The quantitative work was organized into cost reach segments as shown in Figures 2 through 5. Cost reaches were broken out considering a number of inputs including but not limited to: geotechnical deficiencies, changes in landside real estate, major infrastructure crossings, and hydrologic features.

2.9.2 Abbreviations and Names

The following abbreviations correspond to the location names shown on Figures 2 through 5, and for the cost estimating results below. The following abbreviations refer to Table O.

Table O. Names and Abbreviations for Levee Reaches for the North and Central Stockton Area and RD17

Abbreviation	Location Name
ST	Shima Tract (between Mosher Creek and Five Mile Creek)
MC	Mosher Creek
FM	Fourteen Mile Slough
FS	Five Mile Slough (between Shima Tract and Fourteen Mile Slough)
TS	Ten Mile Slough (between Fourteen Mile and Calaveras)
CR	Calaveras River
SDC	Stockton Diverting Canal
MS	Mormon Channel
SJR	San Joaquin River in the areas of the delta, RD404, and RD17
FCS	French Camp Slough
PTC	Potter Creek (SDC extension)
SC	Smith Canal
DC	Duck Creek (French Camp Slough extension)
PC	Paradise Cut

2.9.3 Parametric Estimating

The parametric software tool SPK used to calculate construction quantities is called PCET (parametric cost estimating tool) and is a spreadsheet tool to aid civil design calculate quantities based on known levee templates. The PCET program contains levee fix templates for calculating quantities by inputting geometric variables and design inputs. These variables conformed to EM 1110-2-1913 "Design and Construction of Levees," Sacramento District CESPK-ED-G, SOP-03: "Geotechnical Levee Practice," and ETL 1110-2-583 "Guidelines for Landscaping and Vegetation Management at Levees, Floodwalls, Embankment Dams, and Appurtenant Structures." PCET inputs relied on Urban Levee Evaluation and National Levee Database datasets. These datasets provided geometric templates that could be selected to match the corresponding levee shape for Lower San Joaquin and apply a fix that could be used to calculate quantities efficiently. Unit costs were then applied to PCET outputs in order to determine parametric costs. These unit costs were based on past projects in the vicinity of Sacramento, adapted to the San Joaquin area.

The parametric estimates were used to capture a majority of costs associated with levee flood risk reduction features. Inputs provided to the PCET tool were provided by PDT members using available resources engineering judgment, following USACE criteria and policy. Special study features that could not be estimated with the PCET tool were captured under separate spreadsheet estimates. The cost and schedule risk analysis (CSRA) was also leveraged to account for known/unknown items which have come up in past construction projects.

The PCET tool covered a majority of the proposed levee improvements in the study area as described in paragraph 2.9.5. The tool also included allowances for unallocated items such as permitting, Storm Water Pollution Prevention, and unknown utilities. Site specific features were estimated separately from PCET where appropriate.

2.9.4 Segmental Cost Estimates

Based on experience with similar projects, the PDT began work using small project reach segments which could be incrementally added together for costing alternatives. This was a particularly useful strategy since the hydraulic flood plain and economic analysis work wasn't complete at the time and the alternative extents along with the federal interest was still being defined. The focused array study area contains 92 miles of levee which was evaluated using approximately 130 segments that were on average 3,700 feet in length. The result of this segmentation is presented in Figures 2 through 5. Figure 1 and Table 4 help define the resultant fix locations with relation to the closest index point.

2.9.5 Alternative Estimates

2.9.5.1 General Construction

Various cost estimates were prepared for focused and final array alternatives. The various estimates were based on quantities from geotechnical measures such as new levees, fixing existing levees, or incorporating new features within existing levees. Different types of fixes were then be applied to these measures such as cutoff walls, seepage berms, rock revetments, or general geometric improvements. In addition to these improvements, additional estimates were generated to capture facility and utility relocations resulting from the proposed features. Other cost considerations included real estate acquisitions, environmental and cultural resources mitigation, O&M, design costs, and construction management costs.

2.9.5.2 Construction with Raise

Corps guidance requires that sea level rise be taken into consideration per ETL 1100-2-1-1. The ensuing sea level rise (SLR) factors into the planning for existing project levee heights. The project economics indicated there was federal interest in raising levees to account for SLR in a few locations along RD17, North Stockton, Central Stockton and the Delta Front. In addition to the SLR improvements, there were raises in the lower RD17 area to provide increased assurance of passing the 200-yr event. These improvements were included into all of the alternatives. The sea level rise estimates were added to the final array of alternatives which created LS-7, LS-8 and LS-9. The raises were minimal and the incremental addition of SLR proved to be economically cost justified with increased net benefits. Alternatives LS-2A through LS-4 did not incorporate height improvements for sea level rise, and thus were not considered further for the final array. The list in Table D does not include alternatives LS-2A through LS-4 for this reason.

2.9.5.3 Real Estate

The study initially based the cost estimate of determining affected real estate parcels on the Sacramento District's levee design criteria for a standard 20-foot landside easement. The cost segments were evaluated on land use types which were orchard, agriculture, residential, or commercial. The sponsor requested an exception to reduce the landside easement to 10-feet for the existing federal system levees within the project. The smaller easement was granted since alternatives LS-7a, LS-8a, and LS-9a have on average approximately 600 parcels which would likely require a real estate take if the 20-foot easement were required. The 10-foot easement was only adopted for existing federal system levees where the levee toe remains fixed (i.e. levee fix does not require geometry fix or height raise). For federal system levees, when construction of the levee improvement feature requires the landside toe of the levee to shift, then an additional easement of 10 feet is required for construction and O&M. For levees that are not part of the current federal system, 15 feet landward of the toe is the Corps' policy (this is different than the Sacramento District's standard). If the easement on an existing levee whose toe remains fixed is less than 15 feet as stated above, additional easement must be secured. A waterside easement of 15-feet is required regardless of whether the levee is an existing Federal levee or if it is a new non-Federal levee. Securing the waterside easement is expected to be relatively low in cost and was excluded from the parametric estimates. The cost is to be evaluated during refinements to the recommended plan (formerly the TSP) following adoption of the TSP as the recommended plan.

As the Corps refines the selected plan, for new constructed levees the design will include a 15-foot right-of-way (ROW) per the Corps' ETL measured from the levee toe for both water side and land side. It is anticipated that Sacramento District's policy of a 15-foot ROW will officially be the same as the Corps' policy once the refinement of the selected plan begins. Should a seepage berm, stability berm, or other flood feature be required the ROW is measured from the furthest extent of these features.

2.9.5.4 Operation and Maintenance

Operation and maintenance costs were reflective of additional effort by the local managing agency (LMA) to properly maintain new features. The increased level of effort was qualitatively evaluated and assigned a percentage based on increased O&M cross section and best judgment. The LMA's annual budgets were used to prorate costs per length of maintained area and were multiplied by the increased percentage of effort to obtain an annualized O&M cost. Some of the items that were qualitatively evaluated when determining the increased level of effort were the following.

- Inspection area
- Mowing and vegetation control
- Rodent control
- Pumps, valves, and appurtenances
- Provide periodic increases in levee height to address ground subsidence.

Operation, Maintenance, Repair, Replacement and Rehabilitation (OMRR&R) values did not include the LMA's existing budgets to maintain levee and flood features. In many cases the project improvements should reduce O&M efforts. However, the PDT determined that additional OMRR&R costs should be factored to account for project features which increased LMA O&M efforts over a 50-year design life. Significant contributors to increased LMA O&M efforts were the closure structures at Smith Canal and Fourteen Mile Slough.

These structures considered gate replacement costs and related mechanical maintenance on supporting systems.

2.9.5.5 Encroachments

Department of Water Resources (DWR) levee logs contributed to most of the utility inventory. Other encroachment information was available as GIS data from the City of Stockton and Nation Levee Database. Up to the selection ofthe final array, areas with limited utility coverage used the unallocated item cost within the PCET tool and leveraged the construction cost contingency for estimating purposes. During refinement of the recommended plan (formerly the TSP), additional data became available and a more complete estimate was created. However, short of conducting a utility survey (which wasn't carried out), the information used to date carries risk with respect to completeness of known utilities and the accuracy of their location. The risk being higher PED costs if utilities aren't listed or inaccurately described.

Utility relocation costs were generated from a series of typical penetration conditions. Most often the fix involved raising pipe(s) invert above the design water surface level through the levee. This typically involved replacing the pipeline and adding positive closure valves to meet Corps EM 1110-2-1913 policy.

Table P. provides information about the most significant utility encroachments and the proposed utility modification for the levees of North and Central Stockton.

Table P. Description, and Ownership of Utility Relocation for North Stockton Levees

Owner	Segment/Levee Mile	Description
City of Stockton	CR_80_R: 21.21	Bianchi & Calaveras River Pump Station: Replace /relocate multiple pipes through the levee.
Univ of Pacific	CR_70_R: 22.11	Cut/replace 8-in concrete pipe 5' below crown
City of Stockton	CR_40_R: 23.77	Replace/relocate 33-in sewer force main
City of Stockton	CR_40_R: 23.77	Brookside & I-5 Pump Sta.: Replace/relocate multiple pipes through levee, 5.5' below crown.
City of Stockton	CR_30_R: 24.23	Replace/relocate 5 Discharge Pipes through levee
East Bay Municipal District	TS_10_L: N/A	Pump Station: Protect 2 pipes through levee
City of Stockton	FM_30_L: N/A	Replace/relocate 30-in sewer force main perpendicular to levee
City of Stockton	FM_40_L: N/A	Cut/replace 30-in sewer force main perpendicular to levee
City of Stockton	FM_60_L: N/A	Cut/replace 66-in sewer pipeline
City of Stockton	MC_20_L: N/A	Cut/replace 54-in storm drain pipe

Table Q. Description and Ownership of Utility Relocation for Central Stockton Levees

Owner	Segment/Levee Mile	Description
Unknown	CR_10_L: N/A	Cut/replace pipe and possibly relocate misc power encroachments
Unknown	SJR_40_R: 0.68	Cut/abandon 3-30-in pipes 22' below the crown
City of Stockton	SJR_40_R:0.7	Cut/replace 60-in RCP sewage outfall
Unknown	SJR_40_R: 0.78	Cut/Replace 42-in pipe 18' below crown
City of Stockton	SJR_50_R: 1.08	Cut/replace 36-in concrete encased pipe through levee 15' below crown
Unknown	SJR_50_R: 1.08	Cut/replace sewage outfall pipe through the levee 12.5' below crown
City of Stockton	SJR_60_R: 1.45	Cut/replace 60-in and 2-25-in conduit lines through levee
Unknown	SJR_60_R: 1.43	Cut/abandon 36-in pipe through levee, 20' below the crown
City of Stockton	SJR_70_R: 1.85	Replace/relocate 4-24-in & 1-8-in pipe plus miscellaneous items
City of Stockton	FCS_10_R: 0.22	Cut/replace 8-in pipe, 2.5' below crown
Unknown	FCS_10_R: 0.78	Cut/Replace 16-in pipe, 12' below the crown
Unknown	FCS_10_R: 1.6	Cut/abandon 18-in pipe through levee, 8' below crown
City of Stockton	FCS_10_R: 1.75	Protect in place 2-42-in & 1-72-in pipe under the levee and under channel
City of Stockton	DC_10_R: N/A	Cut/Replace multiple pipes through levee
Unknown	DC_30_R: N/A	Cut/replace 42-in sewer line

A final determination on compensability will be required for specified relocations prior to execution of the Project Partnership Agreement (between the Corps and the non-Federal sponsors). Impacted utilities/facilities, such as those listed above, do not have a final determination as compensable and non-compensable relocations. A final determination of the relocations necessary and for qualifying compensabilities for the construction of the project will occur during PED.

2.9.5.6 Pre-Construction, Engineering and Design (PED), and Construction Management (CM)

The cost estimates included both PED and CM which were assigned a percentage of the construction, environmental mitigation, and utility relocations. PED was assigned a value of 15% based on historical values. CM was assigned 10% of the costs.

2.9.6 Borrow Sites/Disposal Areas

A maximum of 1.4 million cubic yards (cy) of borrow material and 138 acres of borrow lands could be required to construct the project. Because project development is in the preliminary stages of design, and because of the high rate of turnover of borrow areas over time in the Stockton area, detailed studies of borrow needs are likely to change over a shorter timeframe than would be anticipated in other areas. If the project is authorized and funded, detailed evaluation of borrow requirements, identification and detailed technical evaluation of potential borrow sources would be completed during PED.

Excavated and borrow material will be from within a 25-mile radius and would be stockpiled at staging areas. To the extent feasible, borrow material would be obtained from a licensed, permitted facility that meets all Federal and State standards and requirements. In addition, many acres of farmland and vacant land currently exist near the project and borrow could be obtained from these lands. In selecting borrow areas, lands closest to the construction sites would be evaluated for availability and suitability first before evaluating lands further from the project. Haul trucks, front end loaders, and scrapers would bring borrow materials to the site. The material would then be spread evenly and compacted according to levee design plans. The levee would be hydroseeded once construction was completed.

Over half a million cubic yards of unsuitable soil are expected to be disposed of at commercial and local disposal sites. Additionally, some of this soil can be used to mitigate for the borrow areas and fill in low spots. The estimate is that 50% of the excavated material will be able to be reused.

2.9.7 Construction Access, Haul Routes and Staging Areas

For construction and staging areas the early planning analysis indicates that sufficient sponsor, county, or city property exists and that additional areas do not need to be purchased. These local properties in the form of empty lots, right-of-ways, and easements would be available for these functions. Thus, specific access and staging areas were not identified for the feasibility study. In areas where the sponsor lacked proper access or easement, the real estate estimates included cost to obtain the required easements per paragraph 2.9.5.3 which would also be used for access and staging needed to facilitate construction of the flood risk management features.

During the formation of the alternatives, haul routes were not identified. Haul routes are expected to be fairly direct between the borrow areas and the construction. Multiple borrow areas are expected to be located within 25 miles of the construction, some of which are tied to sponsor interests. It is unclear which borrow areas would continue to be viable until the start of construction, and thus the identifying specific haul routes will be required during the PED phase.

2.10 Cost Engineering

2.10.1 General

The cost estimates under the study have been prepared under ER 1110-2-1302 Civil Works Cost Engineering which describes levels of detail with respect to cost. The level of detail is based on ASTM E 2516-06, Standard Classification for Cost Estimate Classification System. The Parametric Cost Estimating Tool (PCET) used to parametrically define the initial and final array of alternatives is based on a Class 4 level of detail. The recommended plan is based on a Class 3 level of detail prepared using computer aided cost software (MCACES) and is referred to as the recommended plan in this report.

Real estate estimates were based on footprint requirements for project construction, operation and maintenance provided by Civil Design Section A. Alternative estimates were prepared based on refinements to the preliminary layouts, features, and measures as determined by screening analysis as performed by Planning Division, and input from the potential non-Federal sponsors. Design guidance for cost estimates comes from ER 1110-2-1302, Civil Works Cost Engineering.

2.10.2 Preliminary Cost Analysis (Array of Alternatives)

This section serves as a history of Cost Engineering results for the final array of alternatives leading to the Tentatively Selected Plan (TSP). There are seven alternatives in the final array as listed below. For descriptions of the alternatives, see Section 2.4.4 – Final Array.

The quantities and project cost estimates for the final array of alternatives were prepared by Civil Design utilizing unit costs for typical construction items as developed by the Cost Engineering Section and other cost data furnished by the Environmental Planning and Real Estate sections. A summary of estimates for the final array of alternatives is provided in the cost engineering addendum.

2.10.2.1 Quantity Takeoffs

Quantities for most project items relative to levee construction/modifications were developed by Civil Design Section using a spreadsheet tool. This spreadsheet utilizes generic cross sections with predetermined cost elements (typical levee work such as clearing and grubbing, earth fill, aggregate base, etc). Civil Design provides quantities for those elements based on input of design levee parameters as determined by the Geotechnical Section.

2.10.2.2 General Methodology in Cost Estimate Preparation

During this period of alternatives study leading to the TSP, ER 1110-2-1302 requires Class 4 Cost Estimates as a minimum. Class 4 estimates are primarily stochastic in nature with an expected accuracy range index of 3 to 12 where the value of ‘3’ represents +30/-15 percent and a value of 12 represents a +120/-60 percent range. In developing the class 4 cost estimates for the alternatives, the Cost Engineering team (Cost Engineers and Civil Design Engineers) utilized a number of different methods to determine project costs.

2.10.2.3 Levee Improvement Cost Summary

Generic/parametric/characteristic unit construction costs for many typical levee improvement elements were developed using estimating software MII (MCACES, 2nd Generation). For a typical element such as a slurry wall or borrow material (acquisition and placement), a unit cost was established based on a 'typical' crew, production rate, material cost, assumed/typical haul distance, etc. Davis Bacon labor rates (2014), MII Equipment rates (2011 Equipment Book), current fuel prices (2014) and generic/typical Contractor markups were utilized to establish unit costs. For any particular levee improvement (such as to fix-in-place the levee by degrading, placing a slurry wall/seepage barrier and restoring the levee), the estimating exercise sums the quantities times the unit costs, adds a percentage for such items as mobilization and demobilization, and indicates a total cost per linear foot of levee improvement.

2.10.2.4 Historical Cost Data

Historical unit costs for some items have been utilized based on cost estimates for past projects in the vicinity of Sacramento. For example, pump station costs were based on costs for similar pump stations developed for the Natomas PACR. Cost data was also supplied by other disciplines, specifically Real Estate and Environmental (Mitigation).

2.10.2.5 Cost Engineering Experience

Cost Engineering judgment and experience was used to base some costs on a percentage of construction costs (e.g. Preconstruction Engineering and Design/PED cost, Construction Management cost). The percentages are based on historical data and typical rates used by SPK Cost Engineers in the past.

Each alternative consists of several separable areas divided into reaches/sub-alternatives of various lengths and each reach has an associated type of levee improvement. The sum of all applicable costs for each reach is entered into a spreadsheet that is a compilation of total project costs. The total project cost summaries (first cost) follow the Civil Works Work Breakdown Structure (CWWBS) code of accounts. Feature Codes typically involved in this estimate are 01-Lands and Damages (Real Estate), 02-Relocations, 06-Fish and Wildlife Facilities, 11-Levees and Floodwalls, 18-Cultural Resource Preservation, 30-Preconstruction Engineering and Design, and 31-Construction Management. The 30 and 31 accounts involve any costs associated with USACE staffing on the project for the federal share and anticipated costs associated with local sponsor costs for the non-federal share. The cost estimate for each Alternative is the summation of the costs from the major cost categories. The costs do not account for life cycle costs.

2.10.2.6 Environmental and Cultural Considerations

The Environmental Mitigation cost estimate is performed by SPK Environmental Planning and provided to Cost Engineering. Since this is a construction cost the contingency applied to this account is the effective contingency derived from the Cost and Schedule Risk Analysis.

Mitigation costs were estimated based on acreages of habitat types impacted per the requirements of the Biological Opinions. Each habitat type's costs were assessed considering onsite mitigation and offsite mitigation. For habitat mitigation, a habitat evaluation was preformed to assess the quality of the existing habitat compared to an estimate of the future with project condition. The results of the habitat evaluation was applied to a cost effectiveness/incremental cost analysis to determine the most cost effective mitigation alternatives for the Government. Mitigation is proposed in quantities ranging from in-kind, to a 2 to 1 ratio or 3 to 1 ratio. Larger quantities of mitigation are only proposed when required by the terms and conditions of the Biological Opinions.

On-site mitigation is preferred because it provides higher habitat compensation values than off-site mitigation because the restoration activities occur on the same area as the area of the impact, and was used to the extent practicable. On-site mitigation costs were coordinated with the Corps' landscape architecture department and were based on past experience for implementation of these types of sites in the area. Additional consideration went into the feasibility of whether or not on-site mitigation was practicable for the impacted habitat type. The cost for offsite mitigation is based on the acreage required multiplied by a standard rate for buying credits from a local mitigation bank.

The Cultural Resources Mitigation cost estimate is performed by SPK Cultural Resources and provided to Cost Engineering. Since this is a construction cost, the effective contingency is derived from the Cost and Schedule Risk Analysis. Mitigation costs were initially set at 1% of the project cost; this has since been revised during the comment period. Revised mitigation costs were estimated based on the size of the proposed project, the number of known cultural resources sites within a portion of the project area, the diversity of site types, and costs for mitigation on other SPK Civil Works Projects of similar scales. Importantly, mitigation costs are a component of the broader compliance process undertaken by SPK, and should not be seen as the total cost of compliance activities.

2.10.2.7 OMRR&R Costs

For a description of how the O&M costs were derived, refer to section 2.9.5.4. Table R(a). provides the annual cost of OMRR&R for each alternative.

Table R(a). Annual LSJ OMRR&R Costs

OMRR&R COSTS		
Alternative	**OMRR&R Annual Cost**	**OMRR&R Lifespan Cost (50 yr)**
7a	$274,800	$13,740,000
7b	$386,700	$19,335,000
8a	$296,600	$14,830,000
8b	$408,500	$20,425,000
9a	$344,800	$17,240,000
9b	$456,700	$22,835,000

2.10.2.8 Total Project Schedule (including Construction)

A formal construction schedule has been developed and the assumption is that the yearly federal monetary allotment for the project will be approximately $100M over 15 ½ years. The initial PED portion of the project is assumed to take about 2 years. The original total duration for construction completion for each alternative in the final array is provided in the following table recognizing that these are pre-recommended plan approximations:

APPROXIMATE DURATION	
Alternative	**Years**
7a	12
7b	15
8a	12
8b	15
9a	12
9b	15

2.10.2.9 Cost Uncertainties & Risk Analysis

There are inherent uncertainties in the costs at this level of design (alternatives analysis) since there is no detailed design, plans or specs. There are also inherent uncertainties as the construction contractor(s) are responsible for obtaining the construction materials, accomplishing the work in a timely manner as per the project due date, using overtime and/or multiple crews to accomplish the same, etc. Funding appropriations are typically uncertain. The Central Valley of California is home to many threatened/endangered species that require much of the work to be done within certain construction windows, typically May-October.

For this project, more than 50% of the costs for this project are directly related to levee improvements. A large percentage of this is obtaining and hauling materials for placement of levee fill or impervious fill material (clay cap). For the purposes of the cost estimate, the assumption has been made that stone material will be placed from the landside (trucked). Stone materials are expected to come from either the Bay Area or the Sierra Nevada mountains.

Much of the existing levee material can be re-used but still must be hauled to/from stockpiles. Impervious fill is assumed to come from within 25 miles (one-way haul). The potential contractors are free to obtain local borrow material that meets the intended specifications. Haul costs in general have some uncertainty as material supply locations are up to the contractor, as well as whether the contractor uses their own trucks or utilizes independent truckers for hauling. Another work feature of high risk/high cost is the seismic strengthening of levees which use deep soil mixing (DSM), which requires significant placement time.

An Abbreviated Cost Risk Analysis (ACRA) using the Cost MCX Abbreviated Risk Analysis Template (spreadsheet) was performed for each of the final array of alternatives. The alternative was divided into its main component areas (e.g. North Stockton, Central Stockton, and RD17) and risks were assessed relative to each area. The summary sheet for each alternative ACRA is provided in the Cost Engineering Addendum.

The ACRA meeting was held 4 NOV 2013 with the project manager and most PDT members. The meeting focused primarily on risk identification using the CRA template and brainstorming techniques. The risk analysis process involved dividing project costs into typical risk elements and placing them into a Risk Register, then identifying the risks/concerns relative to those risk elements, and then justifying the likelihood of the risk occurring and the impact if the risk occurs. A Risk Matrix utilizing weighted likelihood/impacts is used to establish the cost contingency to use for each risk element (work feature) for use in alternatives comparisons. Project risks were identified and the risk register developed within the spreadsheet for the component areas of each alternative. The likelihood of an impact on each risk element was assessed by the PDT. The draft risk register and results were then forwarded to the PDT for review.

Risk elements were identified for each alternative based on the Civil Works Work Breakdowns Structure (CWWBS) and work feature. Prime construction work features identified were Earthwork, Cutoff Walls, DSM walls (Seismic), and Slope/Erosion Protection, These items typically accounted for 80 percent or more of the costs, except for the Central Stockton area, where there are several diversion structures and bridges that are, with remaining construction features such as mob/demob, relocations, and hydroseeding, lumped together in a category for ‘Remaining Construction Items.’ The risk register thus serves the purpose of historical documenting as well as to support follow-on risk studies as the project and its accompanying risks evolve. The results of the ACRA therefore reflect the risk register parameters and are considered adequate for establishing contingencies for alternatives comparison.

To fully recognize its benefits, risk analysis must be considered as an ongoing process conducted concurrent to, and iteratively with, other important project processes such as scope and execution plan development, resource planning, procurement planning, budgeting and scheduling.

2.10.2.10 Screening Level Costs

The costs provided are considered parametrically based and are not refined and are to be used to compare the relative cost between the Alternatives. Focus on the Cost Engineering data has been on the alternatives. Once the PDT has selected the recommended plan (formerly the TSP) and any locally preferred plan (if different from the TSP), Feasibility Level design details and quantities by Civil Design, and Cost Engineering data, must be developed. This includes creation of refined plans in order to update the associated quantities, development of a detailed MII estimate, a Total Project Schedule (including Construction), PDT estimates for Planning, Engineering and Design, an updated Cost and Schedule Risk Analysis and a Total Project Cost Summary (TPCS) extending costs out through the life of the Project. The MII estimate must be detailed indicating labor, equipment and materials with accompanying production rates.

2.10.2.11 Key Assumptions (on Cost Estimates for Alternatives)

2.10.2.11.1 Quantities and Parametric Cost Estimates

The parametric templates (cross sections) for the various levee improvements, or new levees, are representative of levee reaches. Where the design is insufficient to produce detailed quantities for each reach, the use of these typical cross-sections represents quantities adequate to screen alternatives to the point of determining a selected plan. Unit costs utilized are fair and reasonable.

2.10.2.11.2 Haul Distances

Levee Fill Borrow will come from within 25 miles (one-way haul).

2.10.2.11.3 Project Schedule

For purposes of this study, an annual appropriation of 100 million dollars (federal) was anticipated along with the Non-Federal Sponsor's schedule for acquiring rights-of-way. Ultimately, the recommended plan would be constructed in seven reaches over a 14-year period, with project schedule dependent upon the M2 estimate.

2.10.2.11.4 Real Estate

Real Estate Costs are reasonable.

2.10.2.11.5 Environmental Mitigation

Costs provided by the Environmental Specialists in Planning are reasonable.

2.10.2.11.6 PED Costs

A value of 15% of the Federal Share Construction Costs & 15% of Non-

Federal Construction Costs are consistent with those used in recent years for feasibility studies performed by the Sacramento District.

2.10.2.11.7 Construction Management Costs

A value of 10% of Federal Share Construction Costs & 10% of Non-Federal Construction Costs are consistent with those used in recent years for feasibility studies performed by the Sacramento District.

2.10.3 COST ENGINEERING FOR THE RECOMMENDED PLAN

2.10.3.1 BASIS OF ESTIMATE

This section relates general Cost Engineering data for the Recommended Plan (TRP, previously Alternative 7A). For more detail, see the Cost Engineering Addendum.

This estimate is based on the final feasibility report:

San Joaquin River Basin
Lower San Joaquin River, CA
Final Integrated Interim Feasibility Report
September 2017

For preparing a Feasibility Level cost of the recommended plan, ER 1110-2-1302 requires Class 3 Cost Estimates as a minimum. Class 3 estimates are primarily stochastic in nature. In general, the unit costs for the construction features are computed by estimating the equipment, labor, material, required and the production rates suitable for the project features. The baseline feasibility cost estimate was developed from quantity take-off calculations provided by the Sacramento District's Civil Design Section. Levee alignments were provided to Cost Engineering as Google Earth files. No detailed plans/drawings were developed. Supplementary drawings of certain items such as floodwalls were developed to provide some clarity for cost estimating and review.

Due to the large scope, the project is broken into construction contracts by reach. Each reach is assumed to be a separate contract. The type of solicitation is expected to be unrestricted IFB.

2.10.3.2 PROJECT SCOPE/DESCRIPTION

The project provides for flood risk reduction near and around the city of Stockton, CA and consists primarily of the construction of in-place levee improvement measures to address erosion protection and slope stability, seepage, and overtopping (height) concerns. Flood risk management will also be aided by constructing and operating closure structures on Fourteenmile Slough and Smith Canal. Below is a brief description of the design remediation methods.

Erosion protection and slope stability are improved by placing rock

revetment on the waterside of the levee. The rivers, creeks and sloughs are too shallow for barges and placement will be from the land side.
The levee remediation to address seepage is provided through cutoff walls, by degrading the levee and then constructing a cutoff wall utilizing soil-bentonite slurry walls. Cutoff walls are typically through the centerline of the levee. In one reach, a new levee will be constructed, offset from the existing levee. Part of this new levee will utilize deep-soil-mixing (DSM). A grid pattern of DSM walls will provide seismic stability for the levee that overtops it. At one of the crossings of Interstate 5, relief wells are used where the top of levee is below the I-5 bridge deck.

Height improvements to address overtopping concerns include levee raising and new floodwalls or height improvements to existing floodwalls.
Along the levees, there are utilities that need to be relocated or removed. Active utilities such as pressure pipes, irrigation pipes, drainage pipes, electrical, sewer, gas, cable and water lines are to be removed and replaced in order to construct the cutoff walls. Temporary utilities service is to be provided during the service outages. Roads or bike paths on the levee crowns that must be removed in order to demolish or relocate utilities will be replaced. In a few locations, the utilities are of such a size or depth that it is considered to be impractical to provide temporary utility services and at these locations jet grouting is assumed in lieu of cutoff walls.

2.10.3.3 ENVIRONMENTAL AND CULTURAL RESOURCES (UPDATE FROM STUDY OF ALTERNATIVES FOR SELECTION OF TSP)

Mitigation costs were estimated based on acreages of habitat types impacted per the requirements of the Biological Opinions. Each habitat type's costs were assessed considering onsite mitigation and offsite mitigation. For habitat mitigation, a habitat evaluation was performed to assess the quality of the existing habitat compared to an estimate of the future with project condition. The results of the habitat evaluation was applied to a cost effectiveness/incremental cost analysis to determine the most cost effective mitigation alternatives for the Government. Mitigation is proposed in quantities ranging from in-kind, to a 2 to 1 ratio or 3 to 1 ratio. Larger quantities of mitigation are only proposed when required by the terms and conditions of the Biological Opinions.

On-site mitigation is preferred because it provides higher habitat compensation values than off-site mitigation because the restoration activities occur on the same area as the area of the impact, and was used to the extent practicable. On-site mitigation costs were coordinated with the Corps' landscape architecture department and were based on past experience for implementation of these types of sites in the area. Additional consideration went into the feasibility of whether or not on-site mitigation was practicable for the impacted habitat type. The cost for offsite mitigation is based on the acreage required multiplied by a standard rate for buying credits from a local mitigation bank.

The Cultural Resources Mitigation cost estimate is performed by SPK

Cultural Resources and provided to Cost Engineering. Since this is a construction cost, the effective contingency is derived from the Cost and Schedule Risk Analysis. Mitigation costs were initially set at 1% of the project cost; this has since been revised during the comment period. Revised mitigation costs were estimated based on the size of the proposed project, the number of known cultural resources sites within a portion of the project area, the diversity of site types, and costs for mitigation on other SPK Civil Works Projects of similar scales. Importantly, mitigation costs are a component of the broader compliance process undertaken by SPK, and should not be seen as the total cost of compliance activities.

2.10.3.4 OMRR&R UPDATE

For a description of how the original O&M costs were derived, refer to section 2.10.2.7. Table R(a) provides the annual cost of OMRR&R for the recommended alternative based on a 50 year design life. This accounts for subsidence of the non-federal levees with the assumption of a 2 FT high floodwall constructed at the end of 25 years (over 46,800 LF of levee).

Table R(b). Annual LSJ OMRR&R Costs and OMRR& Lifespan Costs

Item	OMRR&R Annual Costs	OMRR&R Life-Span Cost (50 yr)
Recommended Plan	$274,800	$13,740,000
Subsidence (Floodwall built after 25 years)	$1,072,800	$107,280,000

2.10.3.5 MII COST ESTIMATE - NOTES & ASSUMPTIONS

The MII (MCACES, 2nd generation) Cost Estimate is divided into reaches, with each reach assumed to be a separate construction contract. See the Cost Engineering Addendum for summary costs from the MII estimates.

PROJECT SCOPE/DESCRIPTION

The recommended plan has been divided into five levee reaches (typically 4-6 MI long) and two control structures (one at Fourteenmile Slough and one at the Smith Canal). The description of each reach, and typical work involved for each, is as follows:

North Stockton Area

1-North Stockton: Mosher Slough (LB), Stuart Tract (RB), Fivemile Slough (RB)
2-Delta Front: Fourteenmile Slough (LB), Tenmile Slough (LB), San Joaquin River (RB)
3-Fourteenmile Slough Closure Structure
4-Calaveras River (RB)

Central Stockton Area

5-Calaveras River (LB) and San Joaquin River (RB, North Port)
6-Smith Canal Control Structure
7-RD 404 and Duck Creek: San Joaquin River (RB), French Camp Slough (RB), Duck Creek (RB).

ACQUISITION PLAN

The type of solicitation is expected to be unrestricted IFB. All the levee reaches are fairly long with most having several road/highway/interstate crossings and many utility relocations, several for large pipes. The work for any individual reach can probably be performed in one or two construction season, except for the Delta Front. Large business is assumed throughout.

CONTRACTING PLAN

For each reach, the prime contractor expected to be an earthwork contractor responsible for the general site work, borrow site excavation, levee degrading and rebuilding to the restored or new levee height, and bank stabilization. Miscellaneous/General Subcontractors are expected to be utilized for cutoff walls, jet grouting, hydroseeding, and vibration monitoring.

CONSTRUCTION WINDOWS

The total project schedule for this estimate breaks construction for large reaches into seasons based on construction work windows. The construction work window for major Levee Improvement and Relocations construction activities is typically May-Oct, April and November are available for mobilization and demobilization of equipment and non-flood protection items such as hydroseeding that do not change the effectiveness of flood control and drainage system.

OVERTIME

Overtime is included in this estimate. Assumption is 10 hr days, 6 days/week.
TOTAL PROJECT SCHEDULE

The Total Project Schedule including design, pre-construction and construction were developed using MS Project with construction durations based on those developed in MII. These are used to insure the project reaches could, in general, be completed within the construction windows and with the anticipated crews. The Construction Period is 14 years and includes PED. See the Cost Engineering Addendum for the schedule.

BORROW \ DISPOSAL AREAS

The local sponsors have identified three potential Soil Borrow areas, and the furthest is assumed as the general location for borrow. In general, it is about 10-20 MI (one way) to the various reaches. It is uncertain whether all borrow can be obtained from these sites at the time of construction, so some borrow may need to be obtained from local suppliers or by development of new borrow sites by the Contractor. This was considered during the Cost and

Schedule Risk Analysis (see below) and considered low risk. The Sponsor has confirmed that suitable borrow material is available within 25 miles. The assumed landfill is the North County Landfill (San Joaquin County). The haul distance is 15-25 MI (one way), dependent on the reach segment location.

Certain companies in the Stockton area receive such items as green waste, broken concrete, and excavation that may not be satisfactory for reuse in levees, etc. The typical haul distance to these areas is about 10-20 MI (one way).

CONSTRUCTION METHODOLOGY

The construction methodologies are considered standard for most construction work. One exception to standard construction is jet grouting around deep utilities.

UNUSUAL CONDITIONS

Construction of the Control Structures such as those proposed for the project has not been done in the area for many years. Construction may be tidally influenced.

Night work is anticipated at the I-5 road crossings.

UNIQUE TECHNIQUES OF CONSTRUCTION

Deep Soil Mixing and Jet Grouting are considered unique in that relatively few contractors perform this work.

EQUIPMENT AND LABOR AVAILABILITY & DISTANCE TRAVELED

In an urban area such as Stockton and Sacramento (less than 50 MI away), equipment and labor is readily available. Deep Soil Mixing and Jet Grouting rigs are available, but in limited number, and there is a great deal of levee improvement work anticipated in the California Central Valley for the next 10 years or more. For this reason, it is assumed than no more than three DSM rigs are used within any construction reach. The TOTAL PROJECT SCHEDULE reflects this.

LABOR RATES, EQUIPMENT RATES, MATERIAL & FUEL COSTS & SALES TAX

This estimate meets Davis Bacon wage rates for Davis Bacon wage determinations for the state of California as of September 2017.
Equipment unit costs were obtained from historical Quotes or verbal/telephone conversations with Contractors performing like or similar work and the MII/MCACES Equipment Library 2016, Region VII.
Note: Fuel prices are October 2017 using 5 year average of fuel costs for CA from http://www.eia.gov/petroleum/gasdiesel/. Off-road diesel costs are not subject to state and federal excise taxes, so those taxes are removed from off-

road diesel prices.

2.10.3.6 COST AND SCHEDULE RISK ANALYSIS

The scope of the risk analysis was to calculate and present the cost and schedule contingencies at the 80 percent confidence level using the risk analysis processes, as mandated by U.S. Army Corps of Engineers (USACE) Engineer Regulation (ER) 1110-2-1150, Engineering and Design for Civil Works, ER 1110-2-1302, Civil Works Cost Engineering, and Engineer Technical Letter 1110-2-573, Construction Cost Estimating Guide for Civil Works. The study does not include consideration for operation and maintenance or life cycle costs. For further information see the Cost Engineering Addendum.

2.10.3.7 TOTAL PROJECT COST SUMMARY

See the Cost Engineering Addendum for the certified Total Project Cost Summary (TPCS). First Costs are based on 1 Oct 2017 price levels. Fully funded costs are first costs escalated to the midpoint of design or construction (as per the anticipated construction schedule).

REAL ESTATE (01 Account)

The Real Estate cost estimate (01 Account Lands & Damages and Administrative costs) is performed by the SPK Real Estate Division and provided to the Cost Engineering section. The 01 Account Lands and Damages, Relocation Assistance Payment, and New Utility Easements cost estimates were appraised (please refer to the Real Estate Plan for more detail). These technical Real Estate increments estimated by the appraiser are independent of the contingency derived though the Cost and Schedule Risk Analysis (CSRA). The contingencies were provided by the Real Estate Division.

RELOCATIONS (02 Account)
Construction costs for relocation of utilities and roads were developed primarily through the use of MII. Contingency applied to this account is the effective contingency derived from the Cost and Schedule Risk Analysis.

FISH & WILDLIFE FACILITIES - ENVIRONMENTAL MITIGATION (06 Account)

The Environmental Mitigation cost estimate was performed by SPK Environmental Planning and provided to Cost Engineering. Since this is a construction cost the contingency applied to this account is the effective contingency derived from the Cost and Schedule Risk Analysis.

LEVEES AND FLOODWALLS (including erosion protection) (11 Account)

Construction costs for these accounts were developed using MII. Contingency applied is the effective contingency derived from the Cost and Schedule Risk Analysis.

FLOODWAY CONTROL AND DIVERSION STRUCTURES (15 Account)

Construction costs for these accounts were developed using MII. Contingency applied is the effective contingency derived from the Cost and Schedule Risk Analysis.

PLANNING, ENGINEERING AND DESIGN (30 Account)
The cost for Planning, Engineering and Design (PED) is assumed as 17.6% of the Construction Estimate Total, based on historical estimates done by SPK. Contingency applied is the effective contingency derived from the Cost and Schedule Risk Analysis.

For this project, the assumed percentages are as follows:

Project Management	1.60%
Planning & Environmental Compliance	2.14%
Engineering and Design	8.20%
Review, ATRs, IEPRs, VE	0.30%
Life Cycle Cost Updates (costs, schedule, risks)	0.70%
Contracting & Reprographics	1.00%
Engineering During Construction	2.00%
Planning During Construction	0.30%
Project Operations	1.30%

CONSTRUCTION MANAGEMENT (31 Account)
The cost for Construction Management (CM) is assumed as 10% of the Construction Estimate Total, based on historical estimates done by SPK. Contingency applied is the effective contingency derived from the Cost and Schedule Risk Analysis.

For this project, the assumed percentages are as follows:

Construction Management	7.00%
Project Operations	1.30%
Project Management	1.70%

2.11 Value Engineering

A Value Engineering Study was performed on the preliminary alternatives for this project in July 2013 with the final report date of 19 August 2013.

The objectives of the VE study were to validate, refine and optimize alternatives; facilitate communication; and improve value (increase performance and/or reduce cost). By meeting the objectives, the VE study was able to begin the process of identifying a final array of alternatives. The VE study introduced Value Metrics which analyzed cost and performance in order to calculate a project value. By the end of the VE study the effort had identified a draft final array which eventually led to the final array provided in Section 2.4.4 and Table D.

2.12 Environmental Engineering

Engineering Regulation (ER) 1165-2-132, HTRW Guidance for Civil Works Projects requires that a site investigation be conducted to identify and evaluate existing and potential HTRW issues. This HTRW Site Summary report was conducted in accordance with ER 1165-2-132 and ASTM 1526-05, Phase I ESA as a supplemental guidance. Regulatory database search reports and regulatory agencies' websites were reviewed and assessed for HTRW sites in the Study Area, along the 40 miles long levees proposed for new levee construction, modification and upgrades to the existing levees.

The Study Area for this report is defined as an area 40 miles wide along the proposed levees identified for the alternatives. The Lower Mormon Slough section was a separate study and was conducted as a Phase I Environmental Site Assessment (ESA) and was completed in March 2014.

The Phase 1 report provides the data as being reasonably accurate as of May 2014. The status of HTRW sites are constantly changing and new HTRW sites may be added to the regulatory databases over time. Currently unknown HTRW sites may also be located within the study area and would not be included in this report.

The Phase 1 report lists over 100 sites which are located within 0.25 miles of the LSJ proposed levees. The proposed project alternatives share all of the known sites except for seven active/closed sites located near the Calaveras and the Stockton Diverting Canal (LS-8a). An assessment was made of the Phase 1 report list for sites located within approximately 900 feet of the Calaveras/Stockton Diverting Canal portion of the 8a levees which are presented in Table S. below.

Table S. Active and Closed Hazardous Waste Sites Specific to Alternative LS-7a and the Potential for Levee Site Clean-Up as Low, Medium, or Possible During Construction

Site	Possible Contaminant	Distance to Levee (ft)	Active or Closed Site	Potential for Levee Clean-up
Brea Ag Service 1905 N. Broadway	Pesticide, fertilizer, gw contamination	~ 250-ft	Unknown	Possible
Colon Property 5681 E. Marsh Rd.	Junkyard, possible lead in soil	~ 350-ft	Active	Medium
Beacon Property #27 3300 Waterloo Rd.	Gasoline contamination	~ 650-ft	Closed Site	Low
Fisco Warehouse 1648 Shaw Rd.	Diesel contamination	~ 900-ft	Closed Site	Low
Don's Buggy Shop 3245 Wilson Way N	Gasoline contamination	~ 800-ft	Closed Site	Low
Certified Grocers of California 1990 Piccoli St N	Diesel contamination	~ 900-ft	Closed Site	Low
PG&E (Case #2) 4040 West Ln N	Gasoline contamination	~ 900-ft	Closed Site	Low

HTRW clean-up costs for CERCLA-regulated substances (including pesticides and lead) would not be considered project costs. There is a low probability of having significant impacts from contaminated soil based on the information provided in the Phase 1 report and from the results in Table S. Any impacts associated with HTRW for LS-7a are anticipated to be negligible compared to the overall cost of construction. Alternative LS-9 includes the Mormon Channel bypass which was not included in the Phase 1 assessment described above. However, a Phase 1 assessment was provided for Mormon Channel early in 2014. The report highlights multiple locations of surface and subsurface waste along the banks and within the channel. Surface debris characterized in the report can be removed and disposed of properly without much incidence. What is unknown is the extent of the subsurface waste due to the surface waste which is noted. More consideration should be given by the sponsor to understanding the effort relative to the LS-9 HTRW issue if LS-9 is selected as the recommended plan.

Should unanticipated clean-up become necessary, the effort would be considered CERCLA-regulated and a 100% non-Federal cost. The first two entries in Table S are the highest risks associated with alternatives LS-7 and LS-9. The first two entries are sites that are closest to the Stockton Diverting Canal. Should the recommended plan (formerly the TSP) not include the Stockton Diverting Canal in formulation, then most, if not all known clean-up risk can be excluded as a necessary remediation prior to project implementation.

CHAPTER 3 –RECOMMEDED PLAN LS-7a

3.1 General

The proposed alternative is meant to improve the existing levee system and reduce flood risk for the Central and North Stockton areas.

At the agency decision milestone meeting (ADM) held October 5, 2015, the Corps of Engineers made the decision to adopt the TSP and to refine specific features of the project. The refinements included specific design features that hadn't been identified during the tentative selection of the plan. These refinements included specific design features such as cutoff walls, erosion protection, and some new levee along Duck Creek which hadn't yet been identified during the alternative selection process (such as in Table A, B, and C). During the creation of the array of alternatives the PDT team understood that some of the existing levees lacked proper geometric standards, but the team hadn't studied or identified which levees required reshaping. The refinements for all the project features would allow the Corps to derive a better estimate for the cost of designing and constructing the project.

Alternative LS-7a is identified as the recommended plan with higher net benefits than LS-8a and LS-9a. LS-7a is compliant with Executive Order (EO) 11988 which removes RD17 from the study area and therefore is not in conflict with the EO guidance. The EO requires federal agencies to avoid long and short term adverse impacts associated with the occupancy and modification of flood plains and to avoid direct and indirect support of floodplain development wherever there is a practical alternative. LS-7a has a project length of 22 ½ miles and includes geometric improvements to existing levees, cutoff walls, seismic fixes, erosion protection, a control structure, and approximately 1 mile of new levee along Duck Creek. The extent of the project is shown in Figure 15. The history of how LS-7a came about is described in Chapter 2 and specific “a” and “b” designations are described in Table D in Chapter
2. In addition, LS-7a accommodates for height deficiencies due to future sea level rise.

The project includes fixes and new levee along the following tributaries.

- French Camp Slough
- Duck Creek
- Mosher Creek
- Shima Tract
- Five Mile Creek
- Fourteen Mile Slough
- Ten Mile Slough
- Calaveras River

3.1.1 Feature Description – LS-7a

This section provides feature descriptions for Alternative LS-7a. The main features of LS-7a are the North and Central Stockton levee improvements.

All of the individual levee segments that make up LS-7a required either geometric fixes to attain Corps standards and/or a structural improvement was necessary due to through-seepage, underseepage, or seismic deficiencies. These features are described in more detail 3.1.1.1 and 3.1.1.2 below and are captured in Table V.

3.1.1.1 North Stockton Feature

The North Stockton feature length is 13.3 miles requiring 12.3 miles of cutoff wall. A cutoff wall is needed to reduce through and under-seepage. A little less than half of Ten Mile Slough did not require a cutoff wall. Reference Figures 2, 3 and 15 for this information and for other information on the North Stockton area below.

A seismic fix is required for 1 mile of levee in North Stockton. Most of California is under threat of seismic activity and these particular segments are under hydraulic loading for portions of the day which increases the risk of failure during a seismic event. Two sections of Ten Mile Slough require a seismic fix (TS_10L, TS_20L). A setback levee for segment FM_30L provides an opportunity for environmental mitigation for the project. The setback distance will be refined in PED but initial estimates are approximately 100 feet. The existing levee will be degraded to an optimum height that could allow for waters from the slough to inundate these areas and provide valuable riparian habitat to the area. The slough is tidally controlled and when combined with the closure structure it is estimated that the setback will have negligible affects to the hydraulic conditions in the area.

For North Stockton a seepage berm was not recommended due to the higher cost of implementing a seepage berm relative to a cutoff wall. Due to the density of housing and other infrastructure the lack of available real estate precluded the use of seepage berms in the area. A recommendation for a new levee alignment was also not a suggested part of the plan but may be considered in PED to reduce impacts.

Levee geometry improvements are required for 4 miles of the North Stockton levee system. Geometric fixes would be required on Fourteen Mile Slough, the Calaveras River and Ten Mile Slough. Affected segments are FM_30L, FM_60L, TS_10L, TS_20L, and TS_30L.

Erosion protection improvements are required for nearly 5 miles of levee along Fourteen Mile Slough, Five Mile Slough, Shima Tract, and Ten Mile Slough. These segments are located adjacent to lands and waterways which have large fetches allowing wave formation. This erosion protection is needed to reduce wind and wave loading from the delta side during large storm events. The affected segments are FM_30L, FM_40L, FM_60L, FS_10R, ST_10R, ST_20R, TS_20L and TS_30L.

Table T. Details of the Recommended Plan – Alternative 7

BASIN/ CONSTRUCTION CONTRACT	SEGMENT	LENGTH	EXISTING LEVEE SYSTEM[1]	RECOMMENDED IMPROVEMENTS	WIND-WAVE EROSION PROTECTION[2]	RAISE (ft)[2]
NORTH STOCKTON						
CALAVERAS RIGHT BANK LEVEES	CR_10_R	2300	FEDERAL	FIX IN-PLACE W/20-FT CUTOFF WALL	-	-
	CR_20_R	1300	FEDERAL	FIX IN-PLACE W/50-FT CUTOFF WALL	-	-
	CR_30_R	3800	FEDERAL	FIX IN-PLACE W/50-FT CUTOFF WALL	-	-
	CR_40_R	2300	FEDERAL	FIX IN-PLACE W/50-FT CUTOFF WALL	-	-
	CR_50_R	6900	FEDERAL	FIX IN-PLACE W/50-FT CUTOFF WALL	-	-
	CR_60_R	1400	FEDERAL	FIX IN-PLACE W/20-FT CUTOFF WALL	-	-
	CR_70_R	1800	FEDERAL	FIX IN-PLACE W/20-FT CUTOFF WALL	-	-
	CR_80_R	3200	FEDERAL	FIX IN-PLACE W/20-FT CUTOFF WALL	-	-
DELTA FRONT LEVEES	FM_30_L	7000	NON-FED	-SETBACK LEVEE W/50-FT CUTOFF WALL	YES	-
	FM_40_L	1500	NON-FED	HEIGHT IMPROVEMENTS W/50-FT CUTOFF WALL	YES	1.8
	FM_60_L	1600	NON-FED	HEIGHT AND GEOMETRY IMPROVEMENTS W/50-FT CUTOFF WALL	YES	2.7
	TS_10_L	4000	FEDERAL	SEISMIC W/GEOMETRY IMPROVEMENTS	-	-
	TS_20_L	1600	FEDERAL	SEISMIC W/GEOMETRY IMPROVEMENTS	YES	-
	TS_30_L	5900	FEDERAL	FIX IN-PLACE W/50-FT CUTOFF WALL AND GEOMETRY IMPROVEMENTS	YES	-
FOURTEEN MILE CLOSURE STRUCTURE	FM_50_L	300	NON-FED	CONTROL STRUCTURE W/50-FT MITER GATES	-	-
NORTH STOCKTON LEVEES	FS_10_R	1700	NON-FED	FIX IN-PLACE W/50-FT CUTOFF WALL	YES	-
	MC_10_L	6600	NON-FED	FIX IN-PLACE W/50-FT CUTOFF WALL AND HEIGHT IMPROVEMENTS	-	1.4
	MC_20_L	4100	NON-FED	FIX IN-PLACE W/50-FT CUTOFF WALL AND HEIGHT IMPROVEMENTS	-	1.6
	ST_10_R	2600	NON-FED	FIX IN-PLACE W/50-FT CUTOFF WALL	YES	-
	ST_20_R	4100	NON-FED	FIX IN-PLACE W/50-FT CUTOFF WALL	YES	-
CENTRAL STOCKTON						
CALAVERAS LEFT BANK LEVEES	CR_10_L	1700	NON-FED	FIX IN-PLACE W/50-FT CUTOFF WALL	-	-
	CR_20_L	4300	FEDERAL	FIX IN-PLACE W/50-FT CUTOFF WALL	-	-
	CR_30_L	2300	FEDERAL	FIX IN-PLACE W/50-FT CUTOFF WALL	-	-
	CR_40_L	6900	FEDERAL	FIX IN-PLACE W/20-FT CUTOFF WALL AND GEOMETRY IMPROVEMENTS	-	-
	CR_50_L	1700	FEDERAL	FIX IN-PLACE W/20-FT CUTOFF WALL	-	-
	CR_60_L	1600	FEDERAL	FIX IN-PLACE W/20-FT CUTOFF WALL	-	-
	CR_70_L	3200	FEDERAL	FIX IN-PLACE W/20-FT CUTOFF WALL	-	-

Table T. Details of the Recommended Plan – Alternative 7 (cont'd)

BASIN/ CONSTRUCTION CONTRACT	SEGMENT	LENGTH	EXISTING LEVEE SYSTEM[1]	RECOMMENDED IMPROVEMENTS	WIND-WAVE EROSION PROTECTION[2]	RAISE (ft)[2]
	SJR_10_R	2800	NON-FED	FIX IN-PLACE W/50-FT CUTOFF WALL AND HEIGHT IMPROVEMENTS	-	1.8
SMITH CANAL CLOSURE STRUCTURE/ IMPROVEMENTS	SC_30	800	NON-FED	CONTROL STRUCTURE W/50-FT MITER GATES	-	-
	SJR_20_R	2200	NON-FED	SHEETPILE WALL OR RETENTION WALL	-	-
RD 404 LEVEES	SJR_30_R	3500	NON-FED	FIX IN-PLACE W/20-FT CUTOFF WALL AND GEOMETRY IMPROVEMENTS	-	-
	SJR_40_R	4400	FEDERAL	FIX IN-PLACE W/20-FT CUTOFF WALL	-	-
	SJR_50_R	2000	FEDERAL	FIX IN-PLACE W/20-FT CUTOFF WALL	-	-
	SJR_60_R	2100	FEDERAL	FIX IN-PLACE W/20-FT CUTOFF WALL	-	-
	SJR_70_R	4100	FEDERAL	FIX IN-PLACE W/50-FT CUTOFF WALL	-	-
	FCS_10_R	9800	FEDERAL	FIX IN-PLACE W/70-FT CUTOFF WALL	-	-
	DC_10_R	500	FEDERAL	FIX IN-PLACE W/70-FT CUTOFF WALL	-	-
	DC_20_R	2500	NON-FED	NEW LEVEE W/50-FT CUTOFF WALL	-	-
	DC_30_R	1500	NON-FED	New Levee	-	4

Additionally, the project proposes to replace any existing erosion protection (waterside) that gets removed as a result of the fix in-place construction features.

A refinement to the levee improvement in North Stockton was made in the final feasibility design. Reach MC_30_L on Mosher Slough was not included in the recommended plan because it does not meet the minimum flow requirements to establish federal interest. The reach specifics are provided in Figure 15. Minimum requirements of 800 cfs for a 10% (1/10) ACE event and 1800 cfs for a 1% (1/100) ACE event are required to establish Federal Flood Control Authority in CFR 238.7(a).

One control structure has been identified as being necessary at Fourteen Mile Slough for high flow events. This structure would have gates to control water levels on Lincoln and Brookside Village levees. The operation and frequency of the gates will be defined during PED phase, but are expected to remain open normally. Pumping capability is not required for this structure to evacuate interior flood water during events. The probability of a coincident storm and a large high tide event are rare and much of the drainage basin has interior flood detention systems to mitigate the excess waters.

The levees throughout the Stockton area have sporadic areas of vegetation growing on the side slopes and within the easements. Per Corps policy, ETL 1110-2-583 (ETL) requires the clearing of vegetation along the waterside and landside slope and within 15-feet from the waterside toe and 10-feet from the landside toe for existing federal system levees, and up to 15-feet from the waterside and landside toe for non-federal and new levees. The Corps' informal consultation with Federal and State resource agencies leads the Corps to believe that the LSJR Basin Feasbility Study will receive a jeopardy opinion should the Corps adopt the policy set forth in the ETL.

The Corps has concluded that with the support of the sponsor, a variance will be sought for all non-threatening vegetation for the Mosher Slough, Shema Tract, Five Mile Slough and Fourteen Mile Slough levees. A variance is perceived as the most acceptable solution environmentally, but must retain accessibility for maintenance, inspection, monitoring, and flood fighting.

3.1.1.2 Central Stockton Feature

Central Stockton features total 9.2 miles of improvements, all of which include cutoff wall. Reference Figure 2, 3, and 4 for this information and for other information on the Central Stockton area below.

Levee geometry improvements are required for 2 miles of the Central Stockton levee system. Geometric fixes would be required for one levee segment of the Calaveras River and one levee segment of the San Joaquin River. Affected segments are CR_40L, and SJR_30R. Segment SJR_10_R would require height improvements for sea level raise. Levees improvements along Duck Creek are necessary as a result of not improving the RD-17 levee system. These improvements help prevent flanking of the existing levees by high water from the Lower San Joaquin River. The Duck Creek levee segments are DC_20R, and DC_30R, extending to El Dorado Road.

A refinement to the levee improvement in North Stockton was made in the final feasibility design and includes the addition of CR_70_L as part of the recommended plan. This reach was added to the recommended plan to be consistent with the left bank improvements and to meet the intended performance of that particular reach of the Calaveras River. The addition of this reach is noted in Figure 15 at the end of the report.

A control structure is required at Smith Canal at high flow events to keep both banks of Smith Canal from overtopping. The structure would have gates that will remain normally open and close during higher water events. Pumping capability is not a required feature for the reasons given under the Fourteen Mile Slough closure structure.

In the Central Stockton area the locals are considering providing a letter of intent (LOI) for a SWIF or variance for most of the existing levees. This approach includes most of the south bank of the Calaveras River and the north bank of the San Joaquin and French Camp Slough levees. The exception is the Calaveras River segment CR_10_L, the San Joaquin River segment SJR_10_R and SJR_30_R, and Duck Creek segments DC_20_R and DC_30_R. For these segments the sponsor will be seeking a variance.

The above information on a variance is without formal consultation which could lead to further updates. Between the publication of this document and the beginning of PED further guidance could be provided by the Corps for vegetation on levees.

3.2 Estimated Costs

The cost estimate of the recommended plan is based on MII.

3.2.1 Total Cost for LS-7a

The combined costs of North and Central Stockton to achieve the LS-7a alternative is provided in the integrated report.

3.3 Construction Schedule

The construction schedule was formulated on a variety of inputs and best estimates for production rates. The three big design constraints that needed to be evaluated holistically were: annual appropriations, construction production rates, and air emission concerns. Other issues which drive the schedule include PED, and real estate acquisition. While no specific design constraint would drive the schedule, they all serve as inputs to the construction schedule. For the purposes of this study, an annual appropriation of 100 million (federal) was targeted along with real estate constraints of 1 year for properties with clear title and 2 years for real estate acquisitions that would require condemnation.

3.4 Conclusion

Alternative LS-7a is the recommended plan for the Lower San Joaquin Feasibility Study based on the FDA analysis for maximizing net benefits. Alternative LS-7a includes levee fixes for 22 1/2 miles including geometric improvements to existing levees, cutoff walls, seismic fixes, erosion protection, and control structures. The recommended plan includes the construction of approximately 1 mile of new levee along Duck Creek and would include height increases along several reaches.

The cost of the recommended plan is provided in Chapter 3 of the draft report. Approximately 75% of the cost is projected for upgrades to the North Stockton area. Construction can reasonably be expected to last 14 years.

For more information on specific analysis presented refer to the various engineering addendums including: geotechnical engineering, cost engineering, hydrology and hydraulics.

APPENDIX

DISTRICT QUALITY CONTROL

SPK undertook the DQC per EC 1165-2-216, an internal review of basic engineering work focused primarily on fulfilling the project quality requirements for this study. The engineering disciplines which undertook DQC for their particular appendix were civil engineering (for this engineering summary), hydrology, hydraulic engineering, geotechnical engineering, and cost engineering.

DQC efforts for the various appendices were completed on the following dates:

Civil Engineering - Engineering Summary: 4/28/2016; 12/13/2017
Hydrology: 4/21/2016
Hydraulic Engineering: 4/22/2016
Geotechnical Engineering: 2/5/2016
Cost Engineering: 2/8/2016

A QC review and certificate was provided for each of the above Lower San Joaquin Feasibility Study appendices. The DQC methodology for SPK may have included a subsequent review if any additions or modifications were made to the original report. The dates provided above are the last known completed DQC reviews for the respective engineering disciplines.

TABLES

Table 1. Geographical Location and Description of Initial Alternatives for the LSJ Feasibility Study for the North Stockton and Central Stockton Area.

Geographical Location	Alternative	Description of Alternative
North Stockton	A	Delta Front from the intersection of Twin Brooks Lane and I-5 south along the existing levee located west of I-5, west on 5-Mile Slough, then south along the east side of the slough parallel to Hatchers Cir and Fort Donelson Dr encircling the north side of Lincoln Village West and continuing between W. Swain Rd and Canyon Creek Road to nearly Pershing Ave.
North Stockton	B	Delta Front from the intersection of Twin Brooks Lane and I-5 south along the existing levee located west of I-5, west on 5-Mile Slough, then south along the levee parallel to Hatchers Cir and Fort Donelson Dr continuing south along Brookside Road around Brookside Golf and Country Club continuing upstream of the right bank of the Calaveras River to El Dorado Street.
North Stockton	C	Delta Front from the intersection of Twin Brooks Lane and I-5 south along the existing levee located west of I-5, west on 5-Mile Slough, then south along the west side of the slough parallel to Hatchers Cir and Fort Donelson Dr encircling the south side of Lincoln Village West and continuing between W. Swain Rd and Canyon Creek Road to nearly Pershing Ave.
North Stockton	D	From I-5 and Lincoln Village West along the south side of the slough continuing south along Brookside Road around Brookside Golf and Country Club continuing upstream of the right bank of the Calaveras River to El Dorado Street.
North Stockton	E	From the Delta front up the right bank of the Calaveras River past the Stockton Diverting Canal to Cherryland Avenue.
North Stockton	F	Delta Front from the intersection of Twin Brooks Lane and I-5 south along the existing levee located west of I-5, west on 5-Mile Slough, then south along the levee parallel to Hatchers Cir and Fort Donelson Dr continuing south along Brookside Road around Brookside Golf and Country Club continuing upstream of the right bank of the Calaveras River to Cherryland Avenue.
Central Stockton	A	The left bank of the Calaveras River from approximately the intersection of Yacht Harbor Drive and Fairway Drive to the intersection with the Mormon Channel bypass.
Central Stockton	B	The east side of the Delta from just south of Country Club Blvd across the Smith Canal entrance (to Peninsula with closure gate structure). From the left bank of the Calaveras River from approximately the intersection of Yacht Harbor Drive and Fairway Drive to Pacific Avenue.
Central Stockton	C	From just south of the Port of Stockton shipping channel and the San Joaquin River to upstream of French Camp Slough to Walker Slough past I-5 to the first bend past I-5 on Walker Slough.

Central Stockton	D	The left bank of the Calaveras River from approximately the intersection of Yacht Harbor Drive and Fairway Drive to the intersection with the Mormon Channel bypass. The east side of the Delta from just south of Country Club Blvd across the Smith Canal entrance (to Peninsula). From just south of the Port of Stockton shipping channel and the San Joaquin River to upstream of French Camp Slough to Walker Slough past I-5 to the first bend past I-5 on Walker Slough.
Central Stockton	E	From the left bank of the Calaveras River from approximately the intersection of Yacht Harbor Drive and Fairway Drive to Pacific Avenue. Improvements around the existing levee around Smith Canal.

Geographical Location	**Alternative**	**Description of Alternative**
Central Stockton	F	The east side of the Delta from just south of Country Club Blvd across the Smith Canal entrance (to Peninsula with closure gate structure). From the left bank of the Calaveras River from approximately the intersection of Yacht Harbor Drive and Fairway Drive to Pacific Avenue. From just south of the Port of Stockton shipping channel and the San Joaquin River to upstream of French Camp Slough to Walker Slough past I-5 to the first bend past I-5 on Walker Slough.
Central Stockton	G	Diversion and improvement to Mormon Channel capacity of up to 1,200 cfs from Stockton Diverting Canal. The improvements along Mormon Channel would extend over 33,400 linear feet (6.3 miles), and include flood containment berms, bridge and culvert replacements, road relocations and channel clearing. This alternative provides for floodplain restoration in accordance with E.O. 11988 ecosystem/floodplain restoration goals.

Table 2. Geographical Location and Description of Initial Alternatives for the LSJ Feasibility Study for the San Joaquin River RD17 Area.

Geographical Location	Alternative	Description of Alternative
RD17	A	From I-5 at the south fork of Walker Slough around Westin Ranch via French Camp Slough south along the San Joaquin River to State Route 20.
RD17	B	South from State Route 20 along the tieback alignment to South Airport Way.
RD17	C	From I-5 at the south fork of Walker Slough around Westin Ranch via French Camp Slough south along the San Joaquin River along the tieback alignment to South Airport Way. (Alts A+C)
RD17	D	From I-5 at the south fork of Walker Slough around Westin Ranch via French Camp Slough south to Galley Way and French Camp Road. At Galley Way/French Camp Road traverse east, then south along S. Wolfe Way, east along W. Bowman Rd one-fourth the distance to I-5. From this location on Bowman Rd continue directly south to Dos Reis Rd and continue back to SJ River and continue along the tieback alignment to South Airport Way.
RD17	E	From I-5 at the south fork of Walker Slough around Westin Ranch via French Camp Slough south along the San Joaquin River along the tieback alignment to
RD17	F	Weston Ranch Ring Levee – includes new levee around Weston Ranch development plus an extension of RD 404 levees to prevent flanking during lower frequency events. The levees would total 6.3 miles.
RD17	G	San Joaquin River setback and tie-back extension – includes setback levees to limit protection of undeveloped floodplain within RD17. This alternative extends the tieback levee at the southern-most end of the reclamation district to minimize the probability of flanking during high water events. The setback/tie-back covers a total of 21.5 miles of levee.

Table 3. Geographical Location and Description of Initial Alternatives for the LSJ Feasibility Study for the Mormon Channel Bypass and Paradise Cut.

Alternative	Description of Alternative
Mormon Channel	Diversion and improvement to Mormon Channel capacity of up to 1,200 cfs from Stockton Diverting Canal. The improvements along Mormon Channel would extend over 33,400 linear feet (6.3 miles), and include flood containment berms, bridge and culvert replacements, road relocations and channel clearing. This alternative provides for floodplain restoration in accordance with E.O. 11988 ecosystem/floodplain restoration goals.
Paradise Cut	From the San Joaquin River to the intersection of W. Grimes Rd and S. Tracy Blvd.

Table 4. Dominant Failure Mode by Index Point

USACE Index	Failure Mode(s)
BL1	Under-seepage; erosion
BL2	Under-seepage; erosion
BL3	Under-seepage; erosion
BL4	Under-seepage; erosion
BR1	Under-seepage; erosion
BR2	Under-seepage; erosion
BR3	Under-seepage; erosion
BR4	Under-seepage; erosion
CL1	Through-seepage; landside stability; erosion
CL2	Through-seepage; landside stability; erosion
CR1	Through-seepage; landside stability; erosion
CR2	Through-seepage; landside stability; erosion
D1	Erosion; landside stability
D2	Erosion; landside stability
D3	Under-seepage; landside stability; erosion
D4	Landside stability; erosion
D5	Landside stability; erosion
D6	Through-seepage; erosion
FL1	Under-seepage; erosion
FR1	Under-seepage; erosion
LR1	Erosion; under-seepage
LR2	Seepage (through- and under-); landside stability; erosion
LR3	Seepage (through- and under-); landside stability; erosion
LR4	Seepage (through- and under-); landside stability; erosion
LR5	Seepage (through- and under-); landside stability; erosion
LR6	Seepage (through- and under-); erosion; landside stability
LR7	Seepage (through- and under-); landside stability; erosion
SL1	Landside stability; through-seepage
SL2	Landside stability; through-seepage
SR1	Landside stability; through-seepage