CENTRAL VALLEY
FLOOD MANAGEMENT
PLANNING PROGRAM

FloodSAFE
CALIFORNIA

Public Draft

2012 Central Valley Flood Protection Plan

Attachment 8: Technical Analysis Summary Report

January 2012

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

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1.0 Introduction

This section states the purpose of this report, gives background information (including a description of planning areas, goals, and approaches) and provides an overview of the report organization.

1.1 Purpose of this Report

This Technical Analysis Summary Report provides an overview of the technical analysis approach, tools, and data supporting development of the 2012 Central Valley Flood Protection Plan (CVFPP).

1.2 Background

As authorized by Senate Bill 5, also known as the Central Valley Flood Protection Act of 2008, the California Department of Water Resources (DWR) has prepared a sustainable, integrated flood management plan called the CVFPP, for adoption by the Central Valley Flood Protection Board (Board). The 2012 CVFPP provides a systemwide approach to protecting lands currently protected from flooding by existing facilities of the State Plan of Flood Control (SPFC), and will be updated every 5 years.

As part of development of the CVFPP, a series of technical analyses were conducted to evaluate hydrologic, hydraulic, geotechnical, economic, ecosystem, and related conditions within the flood management system and to support formulation of system improvements. These analyses were conducted in the Sacramento River Basin, San Joaquin River Basin, and Sacramento-San Joaquin Delta (Delta).

1.3 CVFPP Planning Areas

For planning and analysis purposes, and consistent with legislative direction, two geographical planning areas were important for CVFPP development (Figure 1-1):

- **SPFC Planning Area –** This area is defined by the lands currently receiving flood protection from facilities of the SPFC (see *State Plan of Flood Control Descriptive Document* (DWR, 2010)). The State of

California's (State) flood management responsibility is limited to this area.

- **Systemwide Planning Area –** This area includes the lands that are subject to flooding under the current facilities and operation of the Sacramento-San Joaquin River Flood Management System (California Water Code Section 9611). The SPFC Planning Area is completely contained within the Systemwide Planning Area which includes the Sacramento River Basin, San Joaquin River Basin, and Delta regions.

Planning and development for the CVFPP occurs differently in these planning areas. The CVFPP focused on SPFC facilities; therefore, evaluations and analyses were conducted at a greater level of detail within the SPFC Planning Area than in the Systemwide Planning Area.

1.4 2012 CVFPP Planning Goals

To help direct CVFPP development to meet legislative requirements and address identified flood-management-related problems and opportunities, a primary and four supporting goals were developed:

- **Primary Goal –** Improve Flood Risk Management
- **Supporting Goals**:
  - Improve Operations and Maintenance
  - Promote Ecosystem Functions
  - Improve Institutional Support
  - Promote Multi-Benefit Projects

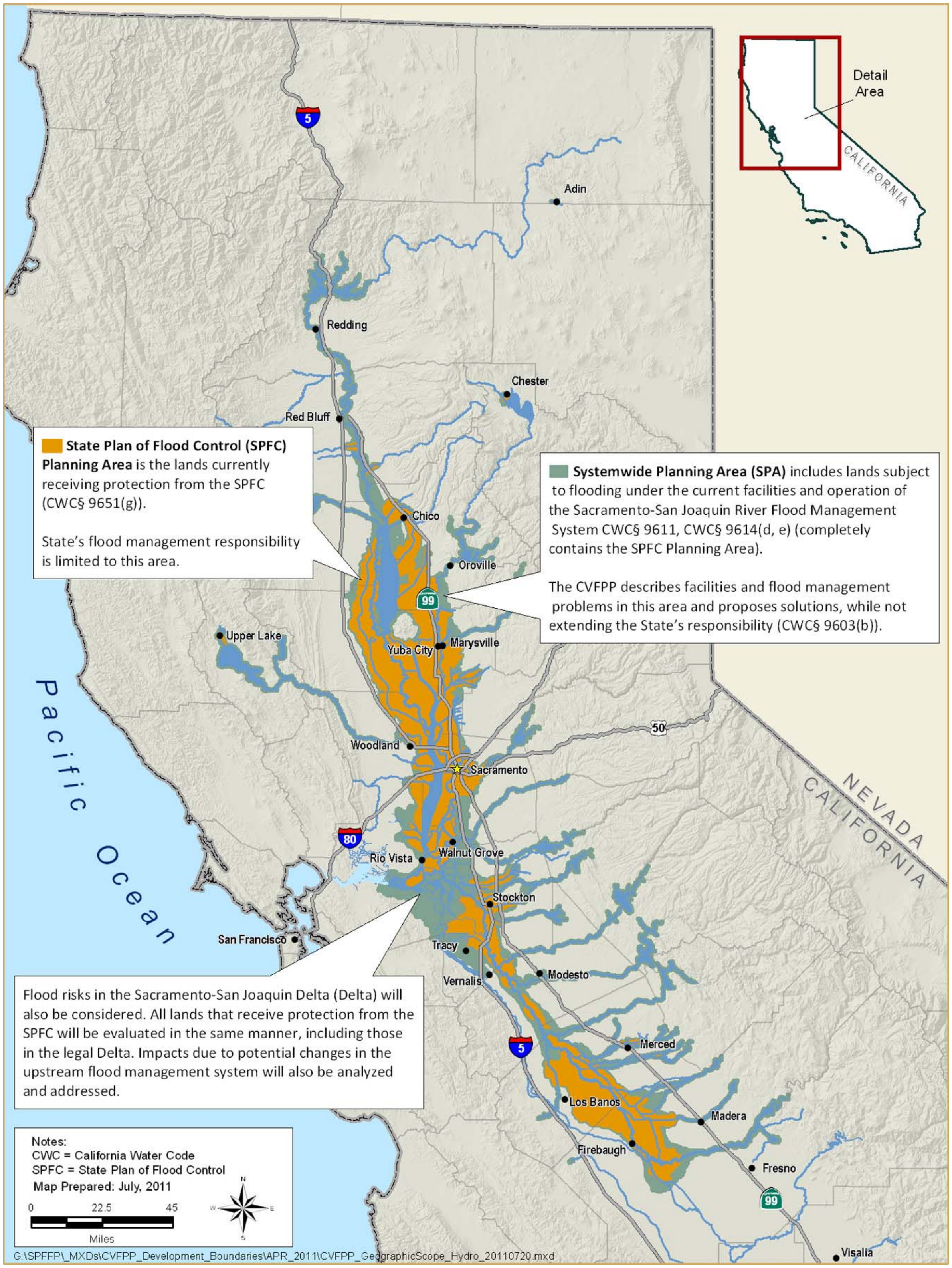

Figure 1-1. Central Valley Flood Protection Plan Planning Areas

1.5 2012 CVFPP Planning Approaches

> **No Project**
>
> - Continuation of existing conditions, including ongoing routine maintenance, floodfighting and post-flood repairs, and other flood management programs.
> - Includes projects that are currently authorized, funded, permitted, and/or under construction.

In addition to the **No Project** approach, three fundamentally different approaches to flood management were initially compared to explore potential improvements in the Central Valley. These approaches are not alternatives; rather, they bracket a range of potential actions and help explore trade-offs in costs, benefits, and other factors important in decision making. The approaches are as follows:

- **Achieve SPFC Design Flow Capacity** – Address capacity inadequacies and other adverse conditions associated with existing SPFC facilities, without making major changes to the footprint or operation of those facilities.
- **Protect High Risk Communities** – Focus on protecting life safety for populations at highest risk, including urban areas and small communities.
- **Enhance Flood System Capacity** – Seek various opportunities to achieve multiple benefits through enhancing flood system storage and conveyance capacity.

Comparing these approaches helped identify the advantages and disadvantages of different combinations of management actions, and demonstrated opportunities to address the CVFPP goals to different degrees.

Based on this evaluation, a **State Systemwide Investment Approach** was developed that encompasses aspects of each of the approaches to balance achievement of the goals from a systemwide perspective, and includes integrated conservation elements. Figure 1-2 illustrates this plan formulation process.

As described above, this summary report describes the numerous technical analyses preformed to support the 2012 CVFPP.

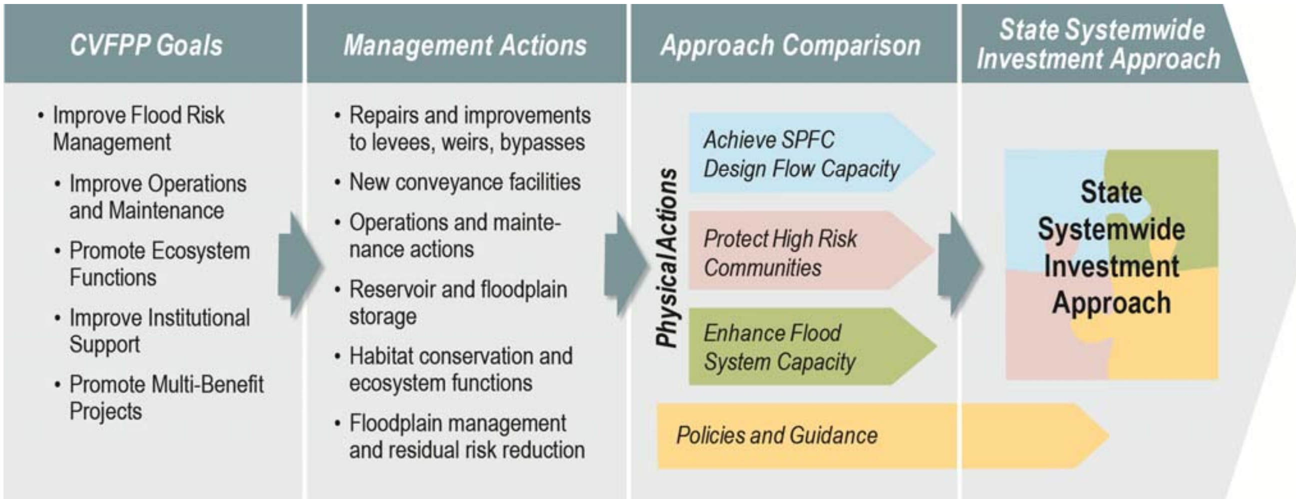

Figure 1-2. Formulation Process for State Systemwide Investment Approach

1.6 Report Organization

Organization of this document is as follows:

- Section 1 introduces and describes the purpose of this report and provides background information.
- Section 2 summarizes the physical approach elements of flood management actions evaluated in the 2012 CVFPP.
- Section 3 provides an overview of the methods used for comparing and evaluating No Project, the three preliminary approaches, and the State Systemwide Investment Approach.
- Section 4 provides an overview of other technical evaluations not used directly in the approach evaluations and comparisons.
- Section 5 describes the anticipated technical evaluation framework for the 2017 CVFP.
- Section 6 contains references for the sources cited in this document.
- Section 7 lists acronyms and abbreviations used in this document.

Attached to this report are 13 technical reports that document the technical analyses performed for the 2012 CVFPP. These documents are named in the List of Attachments section.

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2.0 Summary of Approach Elements Evaluated

Development of the CVFPP included formulating and evaluating three preliminary approaches to explore different potential physical changes to the existing flood management system and to assist in highlighting the need for policy or other management actions. Evaluation and comparison of the approaches focused primarily on the physical elements of the approaches. Technical studies were conducted to determine how physical changes to the system would affect performance of the system as a whole with respect to protecting public safety, reducing flood damages, restoring degraded ecosystems, and contributing to a wide range of multiple benefits. Technical analyses supporting the approach evaluations and comparisons are described in Section 3.

Tables 2-1 through 2-4 list the physical elements included in the No Project, three preliminary approaches, and State Systemwide Investment Approach. These physical elements include the following:

- Reservoir and floodplain storage features
- Bypass and weir modifications
- Flood structure improvements
- Levee improvements in urban areas, small communities, and rural-agricultural areas
- Ecosystem restoration features

Table 2-1. Storage Features Included in Approaches

Flood Management Element	No Project	Preliminary Approaches: Achieve SPFC Design Flow Capacity	Preliminary Approaches: Protect High Risk Communities	Preliminary Approaches: Enhance Flood System Capacity	State Systemwide Investment Approach
Reservoir Storage and Operations					
• Forecast-based/coordinated operations (Yuba/Feather) [1]	■	■	■	■	■
• Folsom Dam Joint Federal Project [2]	■	■	■	■	■
• Modify Lake Oroville release schedule (200 TAF effective increase in storage).				■	
Increase flood storage [3] • New Don Pedro Reservoir – 230 TAF • Friant Dam/Millerton Lake – 60 TAF • New Exchequer Dam/Lake McClure – 100 TAF				■	
Floodplain Storage					
• Sacramento River Basin – 200 TAF • San Joaquin River Basin – 100 TAF				■	

Notes:
[1] Coordinated operations implement two control points at confluence of Yuba and Feather rivers, and Feather River at Nicolaus.
[2] Folsom Dam Joint Federal Project (as authorized) modeled using USACE updated Folsom Dam operations model (provided by Kyle Keer at USACE Sacramento District, February 2011).
[3] Increase in flood storage was modeled as an increase in effective flood space allocation in these reservoirs. This increase can be achieved either through a physical raise of the existing dam or outlet/spillway structures, or reallocation of available storage space between the different water uses.
Key:
SPFC = State Plan of Flood Control
TAF = thousand acre-feet
USACE = U.S. Army Corps of Engineers

Table 2-2. Bypass System and Flood Structure Features Included in Approaches

Flood Management Element	No Project	Preliminary Approaches: Achieve SPFC Design Flow Capacity	Preliminary Approaches: Protect High Risk Communities	Preliminary Approaches: Enhance Flood System Capacity	State Systemwide Investment Approach
Bypass and Weir System					
• Tisdale Bypass and Fremont Weir dredging [1]	■	■	■	■	■
• Sutter Bypass widening • New Feather-Butte Basin Bypass • Fremont Weir widening • Yolo Bypass expansion • Sacramento Weir and Bypass widening • Lower San Joaquin River Bypass (widen Paradise Cut)				■	■
Flood Structure Improvements [2]					
• Gate structure for Feather River Bypass • Butte Basin small weir structures • Upgrade and modification of Colusa and Tisdale weirs • Sacramento Weir widening and automation • Gate structures and/or weir at Paradise Cut • Upgrade of structures in Upper San Joaquin Bypasses • Low-level reservoir outlets at New Bullard's Bar Dam • Fremont Weir widening and improvement • Additional pumping plants and small weirs				■	■
• Cache Creek sediment removal • Sacramento system sediment remediation downstream from weirs				■	■

Notes:
[1] Drawings of Fremont Weir sediment removal (DWR, 2006a) and Tisdale Weir sediment removal (DWR 2006b).
[2] Flood structure rehabilitation, erosion repair, and sediment removal were not modeled as part of any approach because of the negligible hydraulic effects on the system as a whole.
Key:
DWR = California Department of Water Resources
SPFC= State Plan of Flood Control

Table 2-3. Levee Improvement Features Included in Approaches

Flood Management Element	No Project	Preliminary Approaches			State Systemwide Investment Approach
		Achieve SPFC Design Flow Capacity	Protect High Risk Communities	Enhance Flood System Capacity	
Urban Levee Improvements [1]					
FloodSAFE Early Implementation Projects: • Natomas area levees improvements program,[2] Marysville ring levee,[3] Feather and Bear rivers levee improvements [4]	■	■	■	■	■
Levee improvements to pass 200-year water surface [5]			■	■	■
Levee reconstruction to safely pass SPFC design capacity flows [6]		■			
Small Community Levee Improvements [7]					
Protection from 100-year flood event for small communities within the SPFC Planning Area			■	■	■
Rural-Agricultural Levee Improvements					
Levee reconstruction to pass safely SPFC design capacity flows [6]		■		■	
Alternative rural improvements[8]: • Address known deficiencies based on 2011 inspection reports[9] • Restore crown and all-weather access roads					■

Notes:
[1] Urban area is areas with population greater than 10,000. They include Marysville, Yuba City/Live Oak/Gridley, Sacramento area, West Sacramento, Stockton area, and Lathrop and vicinity.
[2] Natomas area levee improvements (as constructed and/or planned/pending) are modeled using levee performance curves developed by the Urban Levees Evaluation (ULE) Program.
[3] Marysville levee improvements (as constructed) were modeled as reconstructed levees because ULE curve was not available. Reconstructed levees were modeled as levees with no probability of failure until overtopped.
[4] Three Rivers Levee Improvement Authority setback levee project (as constructed) was modeled as reconstructed levees.
[5] In simulating improvements to achieve an urban level of flood protection, the 200-year water surface profile from the No Project (baseline) simulation was used as the basis for establishing the probable failure point for urban levees. Actual level of protection in urban areas may be somewhat higher or lower than the 200-year, depending on the effects of other storage and conveyance features included in the approaches.
[6] Reconstructed SPFC levees were modeled as levees with no probability of failure until overtopped. In some reaches, levee crown elevations were increased to address freeboard deficiencies based on the information from the ULE and Non-Urban Levee Evaluation Programs. Level of protection for reconstructed levees varies.
[7] Small communities are areas with population less than 10,000. Small community improvements were not specifically modeled because of the negligible effects of improving small segments of SPFC levees. For the State Systemwide Investment Approach, small communities' protection is also subject to economic feasibility.
[8] Alternative rural improvements were not specifically modeled because of the negligible effects on levee performance curves.
[9] 2011 Inspection Report of the Central Valley State-Federal Flood Protection System. DWR Flood Project Integrity and Inspection Branch.
Key:
SPFC = State Plan of Flood Control

Table 2-4. Ecosystem Restoration Features Included in Approaches

Flood Management Element	No Project	Preliminary Approaches: Achieve SPFC Design Flow Capacity	Preliminary Approaches: Protect High Risk Communities	Preliminary Approaches: Enhance Flood System Capacity	State Systemwide Investment Approach
Ecosystem Restoration Features					
Fish Passage Improvements:[1] • Sutter Bypass and fish passage east of Butte Basin • Freemont Weir fish passage improvements • Yolo Bypass/Willow Slough Weir fish passage improvements • Yuba River fish passage and fish screen • Mendota Pool fish passage and fish screen				■	■
Setback levees:[2] • Lower Feather and Bear rivers • Sacramento River north of Tisdale Weir • Short reaches of Sacramento River south of Tisdale Weir • San Joaquin River between Merced and Stanislaus rivers				■	
Environmental conservation development [3] • For areas within new or expanded bypasses • For areas within connected floodplains in levee setback locations				■	■

Notes:

[1] Fish passage improvements were not simulated because of localized effect on system operations.

[2] Levee setbacks were modeled as 1,000- to 2,000-foot expansion of the floodway corridor, depending on the topography. Levees on both sides of the setback were modeled as reconstructed levees with no probability of failure until overtopped.

[3] Environmental conservation developments in the floodway would be designed to have limited hydraulic effects on the flood carrying capacity of the system. Therefore, these elements were not modeled because of anticipated localized effects.

Key:

SPFC =State Plan of Flood Control

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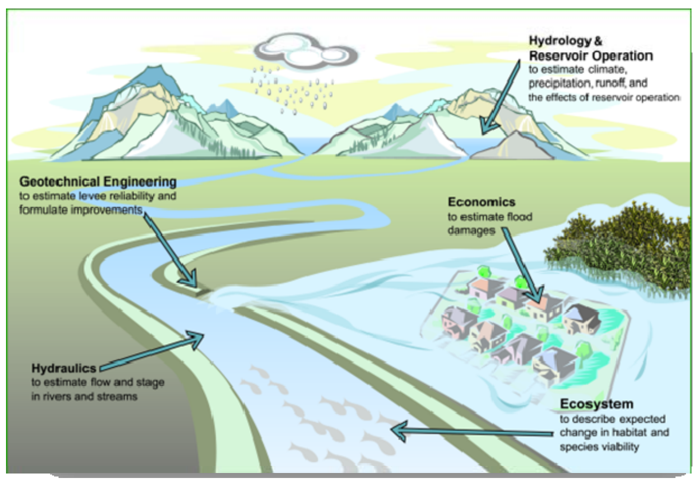
3.0 Evaluation Methods for Approach Comparison

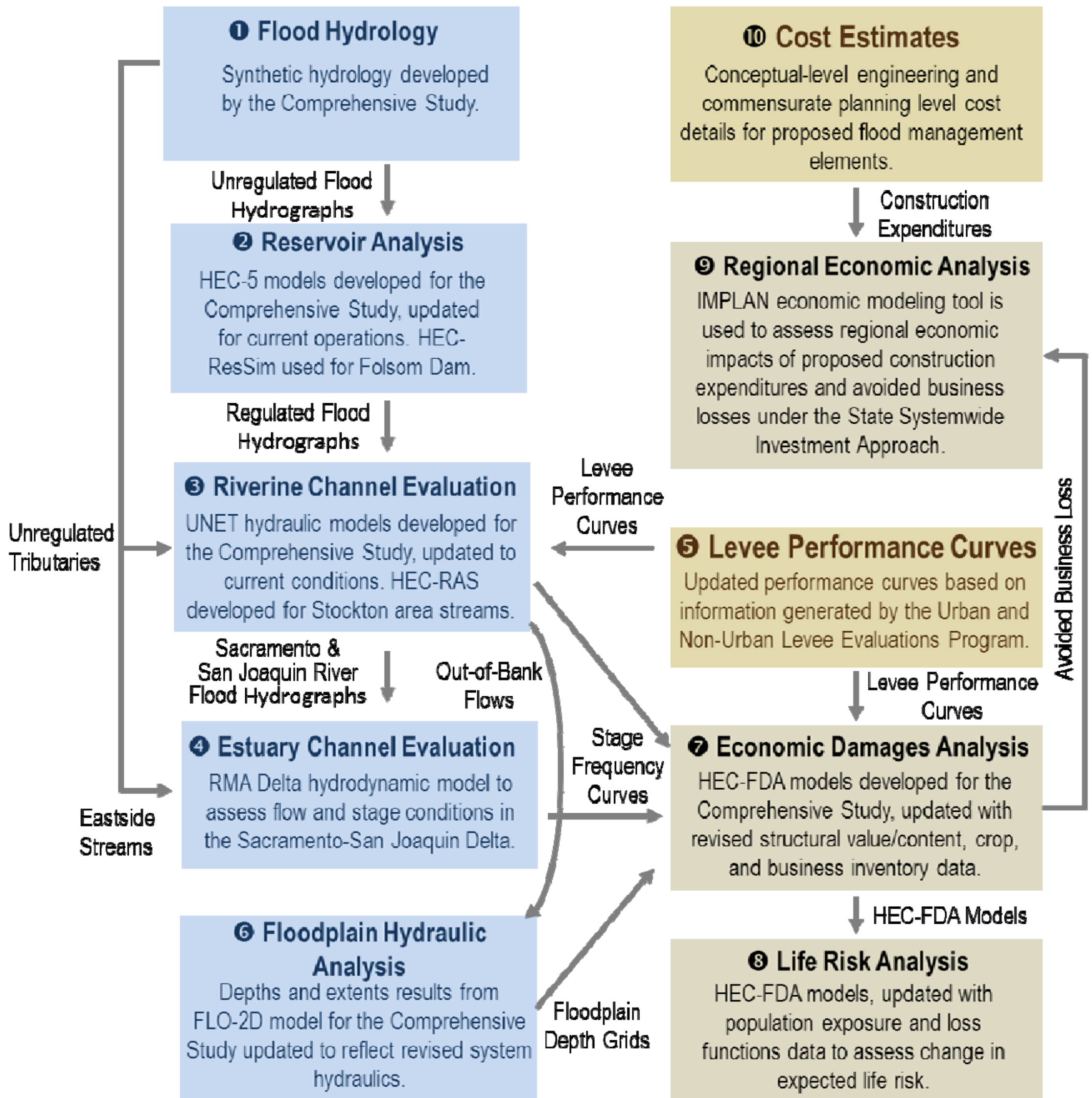
To support development of the 2012 CVFPP, existing and available data and tools were primarily used to help understand the performance of the existing flood management system, and assess the effects of proposed improvements. This section describes the evaluation methods and analytical studies conducted to support evaluation and comparison of the preliminary approaches, and formulation of the State Systemwide Investment Approach.

3.1 Overview of Evalaution Methods



The analytical studies needed to support plan formulation included a series of sequential and parallel evaluations and analyses that commenced with hydrology to develop unregulated flow hydrographs into reservoirs and streams. This was followed by reservoir models to develop regulated flows for the riverine and estuary hydraulic models, which route floodflows and simulate water stages, flow rates, levee breaches, and out-of-bank flows. Geotechnical levee performance characterizations that describe levee failure probability throughout the system provided levee performance curves for the riverine hydraulic models. Out-of-bank flows were routed using floodplain hydraulic models to characterize the extent and depth of floodplains. Risk analysis was then conducted using geotechnical and hydrologic/hydraulic information and uncertainties to assess economic damages and life risk. Conceptual-level design and cost estimates were also developed for the proposed flood management features. Change to regional economic output and employment due to proposed flood improvement was assessed using cost and economic information.

Figure 3-1 illustrates the technical analyses and tools supporting the 2012 CVFPP. These key technical analyses and tools are briefly described in the following sections.



Legend:

Comprehensive Study	*Sacramento and San Joaquin River Basins Study Comprehensive Study (USACE, 2002)*
HEC	USACE Hydrologic Engineering Center
HEC-FDA	HEC Flood Damage Analysis model
FLO-2D	Fullerton, Lenzotti, and O'Brien – Two Dimensional model
HEC-RAS	HEC River Analysis System model
HEC-ResSim	HEC Reservoir Operations Simulation model
HEC-5	HEC Reservoir Operations Simulation model (predecessor to HEC-ResSim)
RMA	RMA Finite Element Model of Sacramento-San Joaquin Delta hydrodynamics
UNET	One-Dimensional Unsteady Network Flow model (predecessor to HEC-RAS)
USACE	U.S. Army Corps of Engineers

Figure 3-1. Technical Analyses and Tools Supporting 2012 CVFPP Development

3.2 Flood Hydrology

Synthetic hydrology was adopted for the 2012 CVFPP based on the "composite floodplain" concept. This concept recognizes that a frequency-based floodplain is not created by a single flood event, but by a combination of several events, each of which shapes the floodplain at different locations. The composite floodplain represents the maximum extent of inundation possible at all locations for any simulated storm events. To construct a composite floodplain, a series of storm centerings, which is a set of storms with different return periods (annual exceedence probabilities), assigned to a set of tributaries, was developed to characterize flooding in different parts of the Sacramento and San Joaquin river basins. This synthetic flood hydrology generated unregulated flow hydrographs into reservoirs and streams. The synthetic hydrology developed for the Comprehensive Study (USACE, 2002) was adopted for the 2012 CVFPP. Details of synthetic hydrology development and use are documented in Attachment 8A: Hydrology.

3.3 Reservoir Analysis

Reservoirs and storage facilities in the Sacramento and San Joaquin river basins provide an important flood management function in regulating flood flows. Using the synthetic flood hydrographs, reservoir models simulate operations of the Sacramento River and San Joaquin River multipurpose reservoirs to generate regulated flood releases. Reservoir analysis for the CVFPP used the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center 5 (HEC-5) reservoir models (USACE, 1998) developed for the Comprehensive Study (USACE, 2002). These HEC-5 models were updated to accurately represent current operations. In addition, HEC Reservoir Simulation (HEC-ResSim) model for Folsom Lake was used to simulate modified releases from Folsom Lake under the Joint Federal Project (Reclamation, 2009). The reservoir analysis evaluated potential changes to flood storage and releases in reservoirs in the Sacrament and San Joaquin river basins to improve flood management. Details of these technical evaluations are documented in Attachment 8B: Reservoir Analysis.

3.4 Riverine Channel Evaluations

Riverine hydraulic models were used to define flow rates and water stages, levee breach locations, and out-of-bank flows along the Sacramento and San Joaquin rivers and their tributaries under various synthetic flood events. The Unsteady Network (UNET) hydraulic model (USACE, 1997) developed for the Comprehensive Study (USACE, 2002) was selected for use in the CVFPP study because it provides extensive coverage of the flood management system in the Sacramento and San Joaquin river basins. These models were updated to represent current conditions, including updated levee performance information and other changes in channel and levee characteristics. In addition, HEC River Analysis System (HEC-RAS) models for the Calaveras River, Mormon Slough, and Bear Creek were developed to simulate streams in the Stockton area. Details of tools updates and technical evaluations are documented in Attachment 8C: Riverine Channel Evaluations.

3.5 Estuary Channel Evaluations

Estuary channel evaluations focused on analyzing potential impacts that occur in the Delta as a result of upstream changes to operations and facilities of the Sacramento-San Joaquin River flood management system. Flows from the riverine hydraulic models for the Sacramento and San Joaquin rivers were the inputs to the estuary channel hydraulic model to develop Delta flows and stages. The USACE version of the Resource Management Associates, Inc. (RMA), Delta hydrodynamic model was used to simulate tidally influenced flow conditions in the Delta (RMA, 2005). Details of these technical evaluations are documented in Attachment 8D: Estuary Channel Evaluations.

3.6 Levee Performance Curves

Updated levee performance curves to reflect levee performance were developed for the entire SFPC levee system in the Sacramento and San Joaquin river basins using information generated by the DWR Urban and Non-Urban Levee Evaluations (ULE and NULE) Programs (URS Corporation, 2010; Kleinfelder, 2010). Performance curves for specific levee segments provided the relationship between river water surface elevation (or stage) and the probability that a levee segment would fail when exposed to that water surface elevation. For each levee segment, performance curves were developed for each failure mode: under-seepage, stability, through-seepage, and erosion. These independent performance curves were then mathematically combined to produce the cumulative or overall performance curve for the segment or reach. These levee performance curves were inputs to the hydraulics and economic models to describe geotechnical probability of levee failure. Details of levee performance curve development are documented in Attachment 8E: Levee Performance Curves.

3.7 Floodplain Hydraulic Analysis

The riverine and estuary hydraulic analyses generated out-of-bank flows caused by overtopping or levee failures. These flows traveling out of stream channels and across the topography of the floodplain were used in the floodplain hydraulic modeling to delineate the floodplains and provide information on floodplain extent and depth for the various synthetic flood events. Floodplain information generated by the Fullerton, Lenzotti and O'Brien – Two Dimensional (FLO-2D) hydraulic models developed for the Comprehensive Study (USACE, 2002) was updated to reflect the change in system performance and levee conditions through developing revised flood depth grids. Details of the development and application of the floodplain information are documented in Attachment 8F: Flood Damage Analysis.

3.8 Flood Damage Analysis

Risk-based analysis of the economic consequences of flood inundation developed estimates of expected (long-term average) annual economic damages. These estimates included structure and content damages, crop damages in inundated agricultural lands, and business income and production losses. To describe the hydrologic, hydraulic, and geotechnical performance of the system and uncertainties, the flood damage analysis used levee performance curves, stage-frequency curves from riverine and estuary hydraulic models, and flood depth information from the floodplain hydraulic analysis. To describe the economic consequences of flood inundation, the analysis used information from a 2010 reconnaissance-level structural inventory, 2010 spatial pattern of cropping, and contents-structure ratios and depth-damage functions (USACE, 2008). The risk-based analysis was conducted using the HEC Flood Damage Analysis (HEC-FDA) model, which computes the expected value of damage while explicitly accounting for uncertainties. Details of the economic evaluations are documented in Attachment 8F: Flood Damage Analysis.

3.9 Life Risk Analysis

Risk-based analysis of the public safety consequences of flood inundation developed estimates of expected annual life risk in similar fashion to the flood damage analysis. The life safety analysis used HEC-FDA models developed for the economic damages analysis to generate annual expected life risk. For population exposure and inundation consequences, the analysis used 2000 U.S. Census population data, which was the best available information at the time the analysis was conducted, and mortality-depth curves (Jonkman, 2007). Details of the life risk evaluations are documented in Attachment 8G: Life Risk Analysis.

3.10 Regional Economic Analysis

Regional economic analysis evaluates the effects of changes in production or expenditures due to proposed flood management improvements on a region's economy. It estimates direct, indirect, and induced employment and economic output effects related to changes in potential business income losses, and proposed construction expenditures to improve flood management facilities. The IMPLAN economic modeling tool was used for the regional economic analysis (Minnesota IMPLAN Group, 2009). This regional economic analysis was conducted only for the State Systemwide Investment Approach. Details of the regional economic evaluations are documented in Attachment 8H: Regional Economic Analysis for the State Systemwide Investment Approach.

3.11 Cost Estimates

Conceptual-level engineering and commensurate level of cost details were developed for the flood management elements included in the CVFPP preliminary approaches and the State Systemwide Investment Approach. These costs were not based on bid-ready engineering documents, but rather on conceptual designs and remedial actions extracted from multiple evaluation efforts. The cost estimates carry an appropriate level of contingency for a conceptual-level planning effort. Details of the cost estimate methodology are included in Attachment 8J: Cost Estimates.

4.0 Additional Supporting Evaluations

Other evaluations not directly used in approach comparison were conducted to investigate potential opportunities for floodplain restoration, assess the effects of climate change on flood management, and identify potential opportunities to incorporate groundwater recharge into flood management activities. These studies are described in the following sections.

4.1 Floodplain Restoration Opportunities Analysis

To support the identification, development, and implementation of specific restoration actions, a Floodplain Restoration Opportunity Analysis was conducted. This analysis identified areas with greater and/or more extensive potential opportunities for ecological restoration of floodplains. These areas were identified through considering physical suitability, and opportunities and constraints related to existing land cover and land uses, locations and physical condition of levees, locations of other major infrastructure, conservation status of land, and locations that stakeholders are interested in restoring.

To evaluate physical suitability, the concept of floodplain inundation potential (FIP) was applied in a geographic information system (GIS) analysis of corridors along the Sacramento and San Joaquin rivers and their major tributaries. To assess physical suitability for restoration actions, the FIP analysis adapted concepts from the HEC Ecosystem Functions Model (HEC-EFM) (USACE, 2009), the Frequently Activated Floodplain concept (Williams et al., 2009), and the Height Above River GIS tool (Dilts et al., 2010). FIP analysis identified areas of floodplain, both directly connected to a river and disconnected from the river (e.g., behind natural or built levees or other flow obstructions) that could be inundated by particular floodplain flows. The flows evaluated by the analysis included a spring flow sustained for at least 7 days and occurring in 2 out of 3 years, and with 2- and 10-year return flood flows.

The identified areas with restoration potential were then prioritized based on location, acreage, and potential ecosystem functions and services. This analysis provides the foundation for subsequent planning efforts to develop specific restoration opportunities in conjunction with planned flood management improvements. Floodplain restoration opportunities analysis is documented in the Supporting Documentation for the Conservation Framework.

4.2 Climate Change Analysis

The prediction of extreme events is one of the most challenging areas for climate change because of the high degree of uncertainties and the limitations of modeling tools and available information. Traditional top-down, risk-based assessments for flood management could not be properly applied because the scenarios from the International Panel on Climate Change do not present a statistical relationship to support the risk analysis (Dessai and Hulme, 2003).

As part of the ongoing development of the 2012 CVFPP, two topic work groups dealing with climate change developed, recommended, and described a unique threshold approach for analyzing climate change in the context of flood management. The Threshold Analysis Approach is a bottom-up approach focusing on vulnerability and associated prudent investments, which aim at broadening the chance of adaptation regardless of which climate change scenarios may be realized, rather than focusing on maximizing the benefits from selected scenarios. The thresholds or vulnerabilities can be assessed at system, regional, and community levels and the concepts are not limited to flood management applications. For the 2012 CVFPP, a pilot study was conducted using the draft Feather-Yuba coordinated operation model developed under the DWR Central Valley Hydrology Study (CVHS). The vulnerability of dam flow release capacity and of downstream flow objectives was assessed in the context of a surrogate index of Atmospheric Rivers (Dettinger, 2011). The results show promise for the proposed methodology, although much work and research are needed for a full application, which is expected for the 2017 CVFPP update. Attachment 8K: Climate Change Analysis documents the climate change analysis conducted for the 2012 CVFPP.

4.3 Groundwater Recharge Opportunities Analysis

Groundwater recharge opportunities analysis identified potential opportunities for enhanced groundwater recharge in conjunction with flood management activities for the dual benefit of increased flood management flexibility and increased water supply reliability. Three broad categories of groundwater recharge were evaluated: recharge projects associated with reservoir reoperation, groundwater banking projects associated with capturing unappropriated floodflows, and recharge associated with activities in the floodplain. This analysis is documented in Attachment 8L: Groundwater Recharge Opportunities Analysis.

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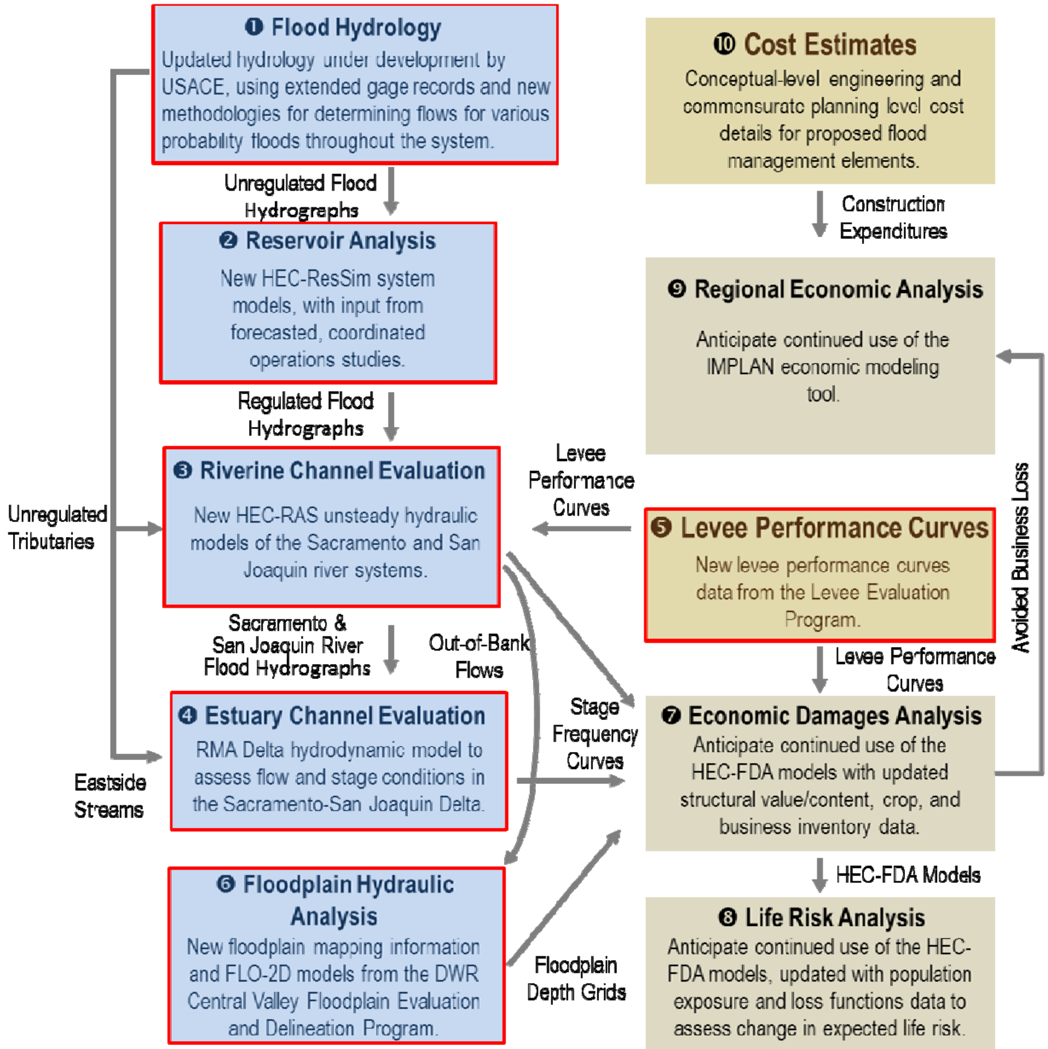
5.0 Continued Tool Development for 2017 CVFPP Update

Currently, multidisciplinary efforts are ongoing to develop new data and tools for use beyond 2012. While results of these efforts will not be available for use in the 2012 CVFPP, this next generation of information will be available to support more detailed technical analyses for the 2017 CVFPP update. Figure 5-1 highlights new information and tools that are being developed to support the 2017 CVFPP update, which are briefly described below:

- Updated flood hydrology being developed in coordination with USACE through the DWR CVHS.
- New reservoir operations models (HEC-ResSim) to simulate the operation of the major flood management reservoirs, under development through the DWR CVHS.
- New riverine hydraulic models (HEC-RAS) to simulate flows in the Sacramento and San Joaquin river channels, under development through the Central Valley Flood Evaluation and Delineation (CVFED) Program.
- Updated floodplain hydraulic models (FLO-2D) to estimate flood depth and extent, under development through the CVFED Program.
- New information from ULE and NULE to inform understanding of the reliability of flood management features in the entire SPFC Planning Area.



Legend:

DWR	California Department of Water Resources
HEC	USACE Hydrologic Engineering Center
HEC-FDA	HEC Flood Damage Analysis model
FLO-2D	Fullerton, Lenzotti, and O'Brien – Two Dimensional model
HEC-RAS	HEC River Analysis System model
HEC-ResSim	HEC Reservoir Operations Simulation model
RMA	RMA finite element model of Sacramento-San Joaquin Delta hydrodynamics
USACE	U.S. Army Corps of Engineers
[red box]	Indicates use of new technical tool or data to support the 2017 CVFPP update

Figure 5-1. New Technical Data and Tools Being Developed to Support 2017 CVFPP Update

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7.0 Acronyms and Abbreviations

Board .... Central Valley Flood Protection Board

CVFED .... Central Valley Flood Evaluation and Delineation Program

CVFPP .... Central Valley Flood Protection Plan

CVHS .... Central Valley Hydrology Study

Delta .... Sacramento-San Joaquin Delta

DWR .... California Department of Water Resources

FIP .... flood inundation potential

FLO-2D .... Fullerton, Lenzotti, and O'Brien – Two Dimensional

GIS .... Geographic Information System

HEC .... Hydrologic Engineering Center

HEC-5 .... Hydrologic Engineering Center 5

HEC-EFM .... HEC Ecosystem Functions Model

HEC-FDA .... HEC Flood Damage Analysis

HEC-RAS .... HEC River Analysis System

HEC-ResSim .... HEC Reservoir Simulation

NULE .... Non-Urban Levee Evaluation

RMA .... Resource Management Associates, Inc.

SPFC .... State Plan of Flood Control

State .... State of California

ULE .... Urban Levee Evaluations

UNET .... Unsteady Network

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

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