California's Flood Future

Recommendations for Managing the State's Flood Risk

PUBLIC REVIEW DRAFT April 2013

California's Flood Future is provided to help inform local, State, and Federal decisions about policies and financial investments to improve public safety, foster environmental stewardship, and support economic stability

FloodSAFE CALIFORNIA

PUBLIC SAFETY ENVIRONMENTAL STEWARDSHIP ECONOMIC STABILITY

US Army Corps of Engineers ®

STATEWIDE FLOOD MANAGEMENT PLANNING PROGRAM

FloodSAFE CALIFORNIA

PUBLIC DRAFT

California's Flood Future: Recommendations for Managing the State's Flood Risk

April 2013

STATE OF CALIFORNIA
THE NATURAL RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

UNITED STATES ARMY CORPS OF ENGINEERS
FLOOD PLAIN MANAGEMENT SERVICES PROGRAM

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The following document is a draft. It has not been finalized and the statements contained within should not be considered the final positions of either the Department of Water Resources or the United States Army Corps of Engineers. Final release of this document is expected in summer 2013, and changes are anticipated based on stakeholder comments and continued agency reviews.

Table of Contents

Acronyms and Abbreviations ix

Executive Summary ..... Highlights

1.0 Introduction 1-1
- 1.1 California's Flood Risk 1-1
  - 1.1.1 Evolution of Flood Management in California 1-1
  - 1.1.2 California's Current Flood Risk 1-9
- 1.2 California's Flood Future Report 1-9
  - 1.2.1 Purpose of Report 1-11
  - 1.2.2 Report Organization 1-12

2.0 Understanding the Situation – California is at Risk 2-1
- 2.1 California is Exposed to Many Types of Flooding 2-1
- 2.2 Flood Management Cannot Be Accomplished in Isolation 2-6
- 2.3 Potential Flood Management Actions 2-7
  - 2.3.1 Nonstructural Approaches 2-7
  - 2.3.2 Natural Floodplain Function Restoration 2-9
  - 2.3.3 Structural Approaches 2-10
  - 2.3.4 Flood Emergency Management 2-12
  - 2.3.5 Crosscutting Approaches 2-13
- 2.4 Flood Risk is Complex 2-14
  - 2.4.1 Flood Risk Basics 2-14
  - 2.4.2 Competing and Conflicting Terminology 2-16
  - 2.4.3 Residual Flood Risk 2-17
- 2.5 Flood Recovery Costs Are High 2-18
- 2.6 Local Agencies Speak Out 2-20

3.0 The Problem – Lives and Property are at Risk 3-1
- 3.1 California is at Risk for Catastrophic Flooding 3-1
- 3.2 One in Five Californians Lives in a Floodplain 3-3
- 3.3 $575 Billion in Structures are at Risk 3-5
- 3.4 California's Agricultural Economy is at Risk 3-7
- 3.5 Critical Facilities Are At Risk 3-10
- 3.6 Environmental Stewardship Suffers from Competing Regulations and Processes 3-13
- 3.7 Future Uncertainties Could Impact Flood Exposure 3-15
  - 3.7.1 How Population and Land Use Changes Impact the Flood Hazard Exposure Analysis 3-15
  - 3.7.2 How Climate Change Impacts the Flood Hazard Exposure Analysis 3-16

Table of Contents

3.8 Existing Flood Infrastructure Does Not Meet Current or Future Needs 3-18
3.9 Flood Management in California is Fragmented 3-22
3.10 Most California Regions Lack Adequate Flood Risk Information 3-26
3.10.1 Inconsistent Risk Assessment Methods 3-26
3.10.2 Data are not Available to Characterize Risk across the State 3-28
3.11 Flood Risk is Not Adequately Understood 3-30
3.11.1 Common Misunderstanding of Residual Risk and Level of Risk Reduction 3-30
3.11.2 Land Use Decisions Can Put People and Property at Risk 3-30
3.12 Funding for Flood Management is Limited and Increasingly Unreliable 3-31
3.12.1 Existing Local, State, and Federal Funding 3-31
3.12.2 Recent California Legislation and Bonds 3-34
3.12.3 Funding Demand 3-36
3.12.4 Funding Challenges 3-45
3.13 Other High-Level Challenges Facing Flood Management 3-47
3.13.1 Sacramento-San Joaquin River Delta 3-47
3.13.2 USACE Public Law 84-99 Relief Policies 3-49
3.13.3 Federal Credit for Non-Federal In-kind Contributions 3-49
3.13.4 Budgeting for Flood Management 3-50
3.13.5 NFIP Modernization 3-52

4.0 The Solution 4-1
4.1 An Integrated Water Management Approach 4-1
4.2 IWM Definition 4-2
4.2.1 Benefits of IWM 4-2
4.2.2 Interaction with Existing Programs 4-3
4.3 We Must Take Action Now. 4-4

5.0 Recommendations for Managing California Flood Risk 5-1

6.0 The Path Forward 6-1
6.1 Approach to Implementing the Recommendations 6-2
6.2 Recommendations Lead to Results 6-4
6.3 Next Steps 6-4

7.0 References 7-1

Attachments

Attachment A: References
Attachment B: Glossary of Terms
Attachment C: History of California Flooding
Attachment D: Summary of Exposure and Infrastructure Inventory by County (Mapbook)
Attachment E: Existing Conditions of Flood Management in California (Information Gathering Findings)
Attachment F: Flood Hazard Exposure Analysis
Attachment G Risk Information Inventory
Attachment H: Practicing Flood Management Using an Integrated Water Management Approach
Attachment I: Finance Strategies
Attachment J: Recommendations to Improve Flood Management in California

List of Tables

Table 1-1. Historical California Flood Events and Flood Management Action Taken in Response (Abridged) 1-4
Table 3-1. Population Exposed to Flooding by Hydrologic Region 3-3
Table 3-2. Value of Structures and their Contents Exposed to Flooding by Hydrologic Region 3-6
Table 3-3. Crops Exposed to Flood Hazard by Hydrologic Region 3-9
Table 3-4. Number of Critical Facilities Exposed within 500-Year Floodplains by California Hydrologic Region 3-10
Table 3-5. Native American Tribal Land and DoD Facilities Exposed within 500-year Floodplains by Hydrologic Region 3-12
Table 3-6. State and Federal Sensitive Species Exposed to Flood Hazard by Hydrologic Region 3-13
Table 3-7. Summary of Ongoing and Potential Flood Projects 3-19
Table 3-8. Primary Agencies with Flood Management Responsibilities 3-24
Table 3-9. Comparison of FEMA and USACE Risk Assessment Approaches 3-27
Table 3-10. Local Planned Projects by Hydrologic Region 3-37
Table 3-11. CVFPP Investment Approach Cost Estimates by Element 3-38
Table 3-12. USACE Planned Projects by Hydrologic Region 3-39
Table 3-13. Estimated Cost of Known Projects/Improvements 3-41
Table 5-1. Matrix of Recommendations versus SFMP Findings 5-3

Table of Contents

List of Figures

Figure 1-1. Examples of Historic Flooding in California 1-3
Figure 1-2. History of Funding for Flood Management in California 1-7
Figure 1-3. Various Documents Developed under the Statewide Flood Planning Management Program 1-14
Figure 2-1. Types of Flooding in California 2-3
Figure 2-2. Role of Agencies in Flood, Water, and Ecosystem Management 2-7
Figure 2-3. Flood Risk Definition 2-15
Figure 2-4. SFMP Participating Flood Management Agencies 2-23
Figure 3-1. Population Exposed to Flooding within the 500-year Floodplain in California by Hydrologic Region 3-4
Figure 3-2. Counties with Largest Population Exposed within the 500-year Floodplains 3-5
Figure 3-3. Counties with Highest Percentage of Population Exposed within the 500-year Floodplains 3-5
Figure 3-4. Structure Values Exposed to Flooding in California by Hydrologic Region 3-6
Figure 3-5. Percentage of Structures Exposed within the 500-year Floodplains 3-7
Figure 3-6. Crop Values Exposed to Flooding within the 500-Year Floodplains by Hydrologic Region 3-8
Figure 3-7. Percentage of Crops Exposed within the 500-year Floodplains 3-9
Figure 3-8. Critical Facilities within the 500-Year Floodplains by Hydrologic Region 3-11
Figure 3-9. State and Federal Threatened, Endangered, Listed, and Rare ("Sensitive") Plant and Animal Species within the 500-Year Floodplains by Hydrologic Region 3-14
Figure 3-10. Sea Level Rise Projections Based on Air Temperatures from 12 Future Climate Scenarios 3-17
Figure 3-11. Projected San Francisco Bay Flood Inundation under a 150-cm Sea Level Rise Scenario 3-18
Figure 3-12. Major Flood Infrastructure 3-20
Figure 3-13. Summary of Ongoing and Potential Local Projects by Hydrologic Region 3-21
Figure 3-14. Number of Agencies with Flood Management Responsibilities by Hydrologic Region 3-23
Figure 3-15. USACE Risk Studies 3-29
Figure 3-16. Average Annual Expenditures on Flood Management in California, 2000-2010 3-32
Figure 3-17. Total Annual Expenditures on Flood Management in California, 2000-2010 3-32

Figure 3-18. Total Annual Capital Expenditures on Flood Management by Entity in California, 2000-2010 3-33
Figure 3-19. Total Annual O&M Expenditures on Flood Management by Entity in California, 2000-2010 3-34
Figure 3-20. General Obligation Water Bond History, 1970-2010 3-36
Figure 3-21. Demand for Flood Management Funding in California 3-44
Figure 3-22. Funding Expenditures for Water Supply, Wastewater, and Flood Management 3-45
Figure 5-1. Organization of Recommendations 5-1

Table of Contents

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Acronyms and Abbreviations

AB	Assembly Bill
ARRA	American Recovery and Reinvestment Act
B/C	benefit-to-cost
BDCP	Bay Delta Conservation Plan
BMP	best management practice
CalEMA	California Emergency Management Agency
CALFED	Collaboration among State and Federal Agencies to Improve California's Water Supply
CDEC	California Data Exchange Center
CEAC	County Engineers Association of California
cfs	cubic feet per second
CIP	Capital Improvement Plan
CLD	California Levee Database
cm	centimeters
CRS	Community Rating System
CSMW	Coastal Sediment Management Workgroup
CVFPP	Central Valley Flood Protection Plan
CW	Civil Works
CWP	California Water Plan
Delta	Sacramento – San Joaquin River Delta
DMMO	Dredged Material Management Office
DoD	Department of Defense
DSC	Delta Stewardship Council
DSOD	Division of Safety of Dams
DWR	California Department of Water Resources
EAD	expected annual damage
EM	Engineer Manual
ER	Engineer Regulation
FCSA	feasibility cost-sharing agreement
FEMA	Federal Emergency Management Agency
FERIS	Flood Emergency Response Information System
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
Flood Future Report	*Flood Future: Recommendations for Managing California's Flood Risk Report*
FloodER	Flood Emergency Response
FPMS	Flood Plain Management Services

Acronyms and Abbreviations

FY	fiscal year
GIS	Geographic Information System
HEC-2	Hydrologic Engineering Center River Hydraulics
HEC-RAS	Hydrologic Engineering Center-River Analysis System
HMP	Hazard Mitigation Plan
HUC	Hydrologic Unit Code
ICT	Incident Command Team
IID	Imperial Irrigation District
IRWM	Integrated Regional Water Management
IWM	Integrated Water Management
IWRM	Integrated Water Resource Management
LHMP	Local Hazard Mitigation Plan
MOU	memorandum of understanding
NED	National Economic Development
NFIP	National Flood Insurance Program
O&M	operation and maintenance
OMB	Office of Management and Budget
OMRR&R	operation, maintenance, repair, rehabilitation, and replacement
PL	Public Law
PPA	project partnership agreement
PRC	Public Resources Code
RD	reclamation district
RFMP	Regional Flood Management Planning
SB	Senate Bill
SFHA	Special Flood Hazard Areas
SFMP	Statewide Flood Management Planning
SHMP	State Hazard Mitigation Plan
SPFC	State Plan of Flood Control
SSIA	State Systemwide Investment Approach
U.S.C.	United States Code
USACE	United States Army Corps of Engineers
WDL	Water Data Library
WRDA	Water Resources Development Act

Executive Summary (Highlights)

The executive summary, *California's Flood Future Highlights (Executive Summary)*, is online at http://www.water.ca.gov/sfmp/resources.cfm#highlights.

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1.0 Introduction

California is at risk for catastrophic flooding that could have wide-ranging impacts due to the size of its economy and the number of people residing in the state. The State's economy ranks ninth globally; therefore, the consequences associated with its potential exposure to property damage, economic harm, and loss of life are great. California is the nation's most populous state, ranks third largest in land size, and has widely varying climates and topographies, all of which make developing one-size-fits-all solutions to flood risk management impracticable.

Flooding in San Dimas Canyon, Los Angeles County

In California, 20 percent of the almost 38 million residents live within 500-year floodplains (i.e., have a 0.2 percent chance of flooding in a given year). Four of the nation's 15 largest cities are in California (Los Angeles, San Diego, San Jose, and San Francisco), and all are at risk for some type of flooding. These factors make decisions regarding California's flood risk management policies and financial investments vital to the State and the nation.

This report, *California's Flood Future: Recommendations for Managing the State's Flood Risk* (Flood Future Report) presents an overview of the flood threats facing the state, approaches for reducing flood risk, and recommendations for managing California's flood risk. The Flood Future Report is the first statewide report to be developed through collaboration between the California Department of Water Resources (DWR) and the United States Army Corps of Engineers (USACE). As a joint report by the State and Federal governments, the document represents an unprecedented level of intergovernmental cooperation, including tribal entities.[1] Additionally, this report would not have been possible without the participation of and information shared by 142 local flood management agencies.

The Flood Future Report represents the first characterization of flood management activities and exposure to flood hazard throughout each county and hydrologic region of the state. This statewide assessment is intended to provide valuable information for local, State, and Federal decision makers as they chart California's complex flood management future.

1.1 California's Flood Risk

1.1.1 Evolution of Flood Management in California

California covers nearly 164,000 square miles, has more than 1,100 miles of coastline, and is home to almost 38 million people (Census, 2010). Californians have settled by and fought to control the 38 major rivers in the state—from the Klamath River in the north to the San Diego River in the south.

[1] Hereafter in this document, the mention of governmental agencies implicitly includes tribal entities.

Flows in California river systems vary tremendously across the state and are driven by regional meteorological conditions, hydrologic conditions, geology, and patterns of human development and encroachment. For example, the flow rate in the Sacramento River system varies from approximately 4,000 cubic feet per second (cfs) to more than 600,000 cfs, depending upon annual meteorological conditions. Water in the Sacramento River system typically rises gradually over time because reservoirs, levees, bypasses, and other infrastructure control the system. Other rivers, such as the Los Angeles River, are dominated by treated wastewater effluent during most of the year and then quickly swell during major storm events. For example, the Los Angeles River captures storm flows from the mountainous areas that surround the city. This precipitation can result in flash flows down the hillsides from the higher elevations. These flash floods in Los Angeles move to the ocean via channelized river systems developed to contain high flows through urbanized areas lower in the basin.

Historic Los Angeles River Flooding

Flooding occurs in all regions of the state in different forms and at different times. Over the last 60 years, California floods have resulted in more than 300 lives lost, more than 750 injuries, and billions of dollars in disaster claims to the California Emergency Management Agency (CalEMA). Every county in California was declared a Federal disaster area at least once for a flooding event in the last 20 years. Figure 1-1 illustrates examples of historic flooding events in California. Table 1-1 provides a sample of historical flood events in California and lists responsive management actions that resulted from those events.

Los Angeles River High Flows Today

Flooding in California can produce beneficial effects and support natural functions (for example, replenishing ecosystems with sediment and nutrients). Flooding also can provide beneficial habitat conditions; however, as people and structures have moved into floodplains, the need for flood management has increased.

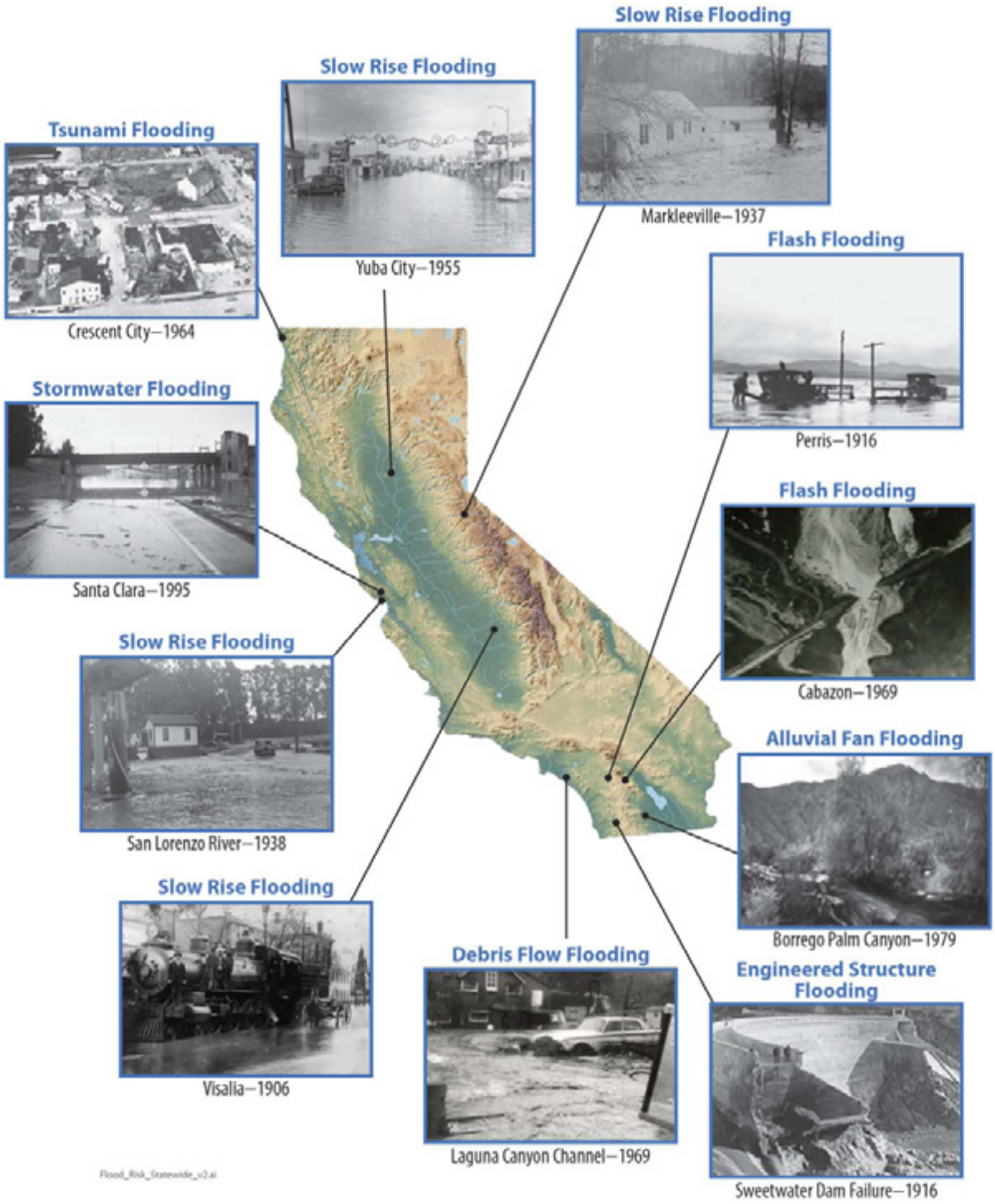

Figure 1-1. Examples of Historic Flooding in California

Table 1-1. Historical California Flood Events and Flood Management Action Taken in Response (Abridged)

Year of Flood	Location	Flood Type	Flood Management Action Taken in Response to Flood Event
1772, 1780, 1805, 1821, 1825, 1832, 1849	Statewide	Slow Rise, Flash Flooding	Development of the California Flood Control Program (DWR, 1965)
1861-1862	Northern California "The Great Flood"	Slow Rise Flooding	Levee construction
1867-1868	Tulare Lake	Slow Rise Flooding	Channel modifications/Improvements
1905-1907	Colorado River (Salton Sea)	Engineered Structure Failure	Repair of Inland Structure
1916	Sweetwater Dam	Engineered Structure Failure	Repair of dam
1927	Santa Ana River, Perris	Flash Flooding	Channel modifications/Improvement
1928	St. Francis Dam	Engineered Structure Failure	Repair of dam
1937	Russian River, Kings River	Slow Rise Flooding	Construction of Coyote Valley Dam (Lake Mendocino). Construction of Pine Flat Dam
1938	Los Angeles River, Inland Desert Areas	Flash Flooding	Lining of channel bed and slopes
1939	Southern California Desert Areas	Flash, Alluvial, Debris Flooding	No action taken
1945	Russian River, Santa Ana River, San Lorenzo River	Slow Rise Flooding	Construction of Coyote Valley Dam (Lake Mendocino) and construction of Prado Dam
1950	Central and Northern California	Slow Rise Flooding	Development of the California Flood Control Program (DWR, 1965)
1955-1956	Central and Northern California	Slow Rise Flooding	Construction of levee, reservoir, and bypass
1958	Central and Northern California	Slow Rise Flooding	Development of the California Flood Control Program (DWR, 1965)
1962	Central and Northern California	Slow Rise Flooding	Development of the California Flood Control Program (DWR, 1965)
1963	Central and Northern California	Slow Rise Flooding	Development of the California Flood Control Program (DWR, 1965)
1964	Crescent City	Tsunami Flooding	Tsunami mitigation measures, including harbor improvements and warning systems
1964	Statewide	Slow Rise Flooding	Variety of actions taken statewide as a result of the December 1964 floods.
1965	Southern California	Flash, Debris Flooding	Channel modifications/improvements
1966	Salinas River, Tule River, Three Rivers, Kaweah River	Slow Rise Flooding	Channel modifications/improvements
1969	Southern California Wide	Flash, Slow Rise Flooding	Construction of Mojave River Dam Channel modifications
1969-1970	Northern California	Slow Rise Flooding	Channel modifications/Improvements
1974	Sacramento River	Slow Rise Flooding	Channel modifications/Improvements

Table 1-1. Historical California Flood Events and Flood Management Action Taken in Response (Abridged)

Year of Flood	Location	Flood Type	Flood Management Action Taken in Response to Flood Event
1976	Southern California Desert Areas	Flash, Alluvial, Debris Flooding	Channel modifications/Improvements
1977	Southern California Desert Areas	Flash, Alluvial, Debris Flooding	Repair Flood Control Basins
1978	Central and Southern California	Stormwater, Flash Flooding	Variety of actions taken locally to address stormwater flooding. Channel modifications/improvements
1980	Southern California Wide	Flash, Debris Flooding	Channel modifications/Improvements
1981-1982	Napa River, Coyote Creek, San Lorenzo River	Slow Rise, Debris Flow, Coastal Flooding	Channel modifications/Improvements
1983	Southern California Wide	Flash, Debris, Coastal Flooding	Channel modifications/Improvements
1983	Northern California	Slow Rise, Engineered Structure Failure, Debris Flow	Channel modifications/Improvements, Levee repair
1986	Northern California "St. Valentine's Day Storm"	Slow Rise, Coastal Flooding	Channel modifications/Improvements, Levee repair
1986 and 1995	Napa River	Slow Rise Flooding	Integrated flood management – living river concept
1995	Central California, Southern California	Flash, Debris, Coastal Flooding	Channel modifications/improvements and bypass tunnel
1996 -1997	Sacramento River and San Joaquin River	Engineered Structure Failure, Slow Rise Flooding	Set-back levee construction and levee repair
1997	Truckee River, Walker River	Slow Rise Flooding	Channel modifications/improvements
1998	Santa Maria River, Tulare Lake Region	Flash, Slow Rise Flooding	Levee reconstruction and upgrading
2003	Devore, Borrego Palm Canyon	Flash, Alluvial Fan, Debris Flow Flooding	Construction/rehabilitation of debris basin
2004	Sacramento-San Joaquin River Delta – Jones Tract	Engineered Structure Failure	Rebuild levee and dewater island
2005	Mojave River	Flash Flooding	Debris dam cleaning and rehabilitation
2006	Napa River	Slow Rise Flooding	Channel modifications/Improvements and ecosystem restoration
2008	San Diego	Flash Flooding	Channel modifications/Improvements
2011	Crescent City, Santa Cruz, Moss Landing, Morro Bay, Santa Barbara, Port Hueneme, San Diego, Orange County beaches	Tsunami Flooding	Repairs ongoing

In the 1800s, flood management was the responsibility of individual landowners (Kelley, 1989). Catastrophic floods in the late 1800s and early 1900s changed the perception of floods, prompting a series of flood management statutes that increased the responsibility of Federal and State agencies for flood management, as well as the development of flood management infrastructure. During this timeframe, flood management consisted primarily of structural solutions such as dams, levees, reservoirs, and floodwalls.

In the 1960s, studies revealed that continued development in floodplains was increasing residual flood risk. As a result, local, State, and Federal agencies began developing policies and programs that managed floodplains in addition to implementing structural solutions for controlling floodwater (FEMA, 2010).

Residual risk is the likelihood of damage or other adverse consequence remaining after flood management actions are taken

Since that time, nonstructural solutions have evolved to include emergency preparedness, response and recovery, flood insurance, operations and warning systems, flood awareness efforts, and restoration of natural floodplain functions to reduce residual risk. Contemporary flood management practices are further evolving to consider a more holistic, Integrated Water Management (IWM) approach in addition to structural and nonstructural solutions to reduce flood risk.

IWM is an approach to planning and project implementation that combines specific flood management, water supply, and ecosystem actions to deliver multiple benefits.

The State of California and USACE have worked for decades to reduce the risk and consequences of flooding in California. Also, many local agencies have taken steps to reduce flood risks in their communities. Flood management officials agree that these improvements prevented recent flood events from becoming major flood disasters, but much more remains to be accomplished to reduce Californian's risk from the negative effects of flooding. In fact, significant flood management improvements are needed across the state. Figure 1-2 shows a timeline of significant flood management actions and funding mechanisms that have been developed starting in the 1850s.

Starting with the Gold Rush, initial major infrastructure was put in place to bring land into production. Over the next several decades, multipurpose infrastructure projects were built. In the latter decades of the 1900s, investment shifted to environmental protection projects. Shifts in financing eras are a result of major events and are generally reactive in nature. This century has seen not only several State bonds passed to rehabilitate and improve infrastructure, including flood management, but also significant Federal funding. Historically, funding for flood management in California has been provided by a combination of local, State, and Federal agencies. The State applied focused attention on flood management issues with the 2006 launch of FloodSAFE California, a statewide initiative to address flood risk. In 2007, California voters passed General Obligation Bond measures to help fund the type of work being developed by FloodSAFE programs, and the California State Legislature passed laws to reduce the consequences from flooding. One of the key outcomes of FloodSAFE is the Central Valley Flood Protection Plan, which

established a State Systemwide Investment Approach for flood management improvements in California's vulnerable Central Valley. Other DWR and USACE flood management accomplishments are presented in Textbox 1-1.

	1850 - 1920	1920 - 1950	1950 - 1970	1970 - 2000	2000 - Current
Theme of Era	Land reclamation	Federal Investment	Infrastructure Expansion	Water Resource Development/ Environmental Protection	Current State Bond Funding
Significant Actions	• Levee construction in Central Valley, San Francisco Bay Area, and Sacramento-San Joaquin Delta • Dam/Reservoir construction • Los Angeles River channelization	• Central Valley Project • USACE and Reclamation involvement in water conservation, water supply, flood management, and wildlife protection projects	• State water project constructed • National Flood Insurance Act of 1968 • Continued flood infrastructure development	• Water Resources Development Act passed (1974) • State and Federal environmental laws enacted (Clean Water Act, Endangered Species Act, California Endangered Species Act California Environmental Quality Act)	• State bond funded infrastructure improvements, planning and emergency management preparedness projects
Financing Mechanisms	• Levee construction by land owners and reclamation districts • Federal funding of flood control projects (e.g. Los Angeles River and, Sacramento River Flood Control Project)	• Flood Control Act of 1928 – Authorized the USACE to construct projects on the Sacramento River for flood control	• General obligation bonds for State Water Project • Utility rates, revenue bonds ,and fees fund local agency projects • 1973 statute required local and State cost sharing of projects (Senate Bill 399 Sec 12585.2 of the California Water Code, Amended in 1973 (Chapters 893))	• Clean Water Act funds variety of Federally authorized projects • 1973 Way Bill (California Water Code §12980-12991) set requirements for State funding of non-project levee maintenance and improvement costs.	• Passage of several Propositions with flood management components •Prop 13 •Prop 12 •Prop 40 •Prop 50 •Prop 1E •Prop 84

Figure 1-2. History of Funding for Flood Management in California

The recent bonds, as well as other State and Federal resources, have funded many critical repairs and other important actions to reduce flood risk throughout California. However, funding resources provided by the recent General Obligation Bonds will be expended by 2017.

Textbox 1-1: DWR Major FloodSAFE Accomplishments

The passage of Propositions 1E and 84 in 2006, with a combined funding capability of nearly $5 billion for flood risk reduction programs enabled the establishment of the FloodSAFE Program. This program has funded and implemented significant achievement statewide over the last 5 years including:

Flood System Risk Assessment, Engineering, and Feasibility Accomplishments

- Provided 7,800 square miles of Laser Imaging Detection and Ranging (LiDAR) surveys in Central Valley including sharing data with 95 agencies
- Developed hydrology and hydraulics for Central Valley Streams within SPFC
- Conducted Phase 1 geotechnical assessment of Central Valley levees including 1,600 miles of levee evaluations

Flood Emergency Response Program Accomplishments

- Developed library of models and enhanced flood forecasting including 94 new forecast points
- Provided $5 million in financial assistance to five Delta Counties for improved emergency communication
- State-Federal flood control system inspection and documentation
- Developed the Federal Emergency Response Exchange (FERIX), a web interface to share and exchange flood management information
- Added three new Incident Command Teams (ICTs) and provided updated equipment to all ICTs

Flood Management Planning Accomplishments

- Prepared the *Central Valley Flood Protection Plan* (CVFPP)
- Prepared *California's Flood Future: Recommendations for Managing the State's Flood Risk*

Floodplain Risk Management Accomplishments

- Identified 2,205 square miles of land protected by SPFC levees and created Levee Flood Protection Zone (LFPZ) maps
- Provided 26,500 river miles of 100-year advisory flood event maps
- Completed more than 260 community assistance visits and 128 local floodplain management training workshops
- Developed written annual flood risk notice and mailed notices to more than 350,000 distinct property in the Central Valley between 2010 and 2012

Flood System Operations and Maintenance Accomplishments

- Rehabilitation of Knights Landing Outfall Gates and Replaced the Garmire Road Bridge
- Rehabilitation and modernization of Sutter Bypass Pumping Plants' control systems
- Made a 900-foot emergency repair for the Natomas Cross Canal
- Repaired over 120 critical erosion sites and proactively repaired over 220 levee sites

Flood Risk Reduction Projects Accomplishments

- Early Implementation Program: over 44 miles of SPFC levees constructed or repaired
- Constructed or Improved over 30 miles of SPFC levees as well as continued construction of Folsom Dam Auxiliary Spillway in partnership with USACE

1.1.2 California's Current Flood Risk

Even with a history of continuing investment and action by local, State, and Federal flood management agencies, residual flood risks exist in every California county. In addition to tragic loss of life, flooding in California can have a serious impact on the State's economy, the national economy, and environmental resources.

Today, more than 7 million Californians, or one in five, live in a floodplain along with approximately $580 billion in assets (crops, structures, and public infrastructure, excluding transportation facilities and utility pipelines) are exposed to flooding within the 500-year floodplain. These estimates do not include the impacts of future development, population changes, climate change, wider economic impacts due to loss of transportation, utilities, and critical facilities, or losses to State commerce. California's current exposure to flooding is discussed in detail in Chapter 2.

1.2 California's Flood Future Report

The Flood Future Report is an initial step to assess the level of flood exposure statewide, identify flood management issues, and develop recommendations to help address California's flood risk. This report is the first product of DWR's State Flood Management Planning (SFMP) Program. The SFMP Program was developed under the FloodSAFE Initiative to expand the focus of California's flood management planning statewide in compliance with Public Resources Code (PRC) Section 75032. The SFMP Program was funded under Proposition 84 as part of the DWR FloodSAFE Initiative and Integrated Water Management Program.

Specifically, the purpose of the SFMP Program is to make recommendations to inform flood management policies and investments in the coming decades by:

- Promoting understanding of flood risks in all regions of California
- Garnering active support for partnerships at the local, State, and Federal levels, including tribal entities
- Coordinating synergistically with other DWR planning efforts
- Promoting an IWM approach for flood management solutions
- Identifying strategies and feasible next steps to better incorporate flood management into IWM

Flooding at Del Mar Racetrack, 1980

The initial work of the SFMP Program was to cover all regions of California to collect information in support of the Flood Future Report, as well as to build partnerships with local flood management agencies, the County Engineers Association of California (CEAC), Federal Emergency Management Agency (FEMA), and USACE. Throughout the Flood Future Report, determinations about specific flood terms were made that may not represent the specific terms used by partner agencies. These are described in Textbox 1-2. A description of the Flood Future Report components, organization, and layout is provided in Section 1.2.2.

Textbox 1-2: Agencies Differ in Flood Terminology

One of the challenges in a multi-agency effort is resolving language and culture differences between agencies. Staff from both USACE and DWR who are responsible for developing this report have made a conscious choice to adopt certain terminology throughout the documents.

As an example, USACE has adopted flood risk management as the term to describe a broad flood program that encompasses planning, construction, and operation, maintenance, repair, rehabilitation, and replacement (OMRR&R). DWR executes a similar broad program, largely through its Flood Management Division. As a result, DWR uses the term flood management in much the same way USACE uses flood risk management.

Another term used throughout this document is 100-year flood (or some other x-year flood). Although these terms are commonly used, both USACE and DWR prefer using 1 percent chance flood (or a 1-in-100-chance event) to describe a flood that has a 1 percent chance of occurring in any given year. However, legislative language from 2007 directing DWR to undertake new planning using bond proceeds uses 100-year flood.

For Federally funded projects, the definition of operation and maintenance (O&M) includes the local entity's financial obligation to OMRR&R of the implemented project. OMRR&R is a non-Federal responsibility when local, regional and/or State entities partner on a Federal project. DWR typically uses O&M to refer simply to operation and maintenance, although repair and rehabilitation are sometimes included depending on project specifics. References to O&M provided in this report include OMRR&R responsibilities when the project is a Federal/non-Federal partnership.

For this report, both agencies agreed that, although language and cultural differences remain, it is more important to focus on the shared responsibility of performing our flood risk management or flood management missions rather than the use of specific phrases not in each agency's respective culture. A glossary is included to help the reader understand specific terms used by flood professionals and those terms that are used to define specific agency missions.

In the Flood Control Act of 1960, Congress granted USACE the authority to compile and disseminate information on floods and flood damages, as well as the authority to provide engineering advice in planning to reduce flood hazards to non-Federal interests (see United States Code [U.S.C.] 33 U.S.C. 709a). Through Section 206 of the Flood Control Act of 1960 (Public Law [PL] 86-645, as amended), Congress established the Flood Plain Management Services (FPMS) Program and assigned USACE to manage the program. The objective of the FPMS Program is to foster public understanding of the options for dealing with flood hazards and to promote prudent use and management of floodplains. Under the FPMS Program authority, USACE has entered an agreement with DWR to provide advice and information in support of this Flood Future Report. In furtherance of this agreement, the USACE has worked closely with experts at DWR to compile and analyze the information summarized in this report. USACE has provided technical information and advice regarding the evaluation of flood risk in California and the consequent planning that is required to address such risks.

1.2.1 Purpose of Report

The purpose of the Flood Future Report is to produce the first statewide look at flood hazard exposure for all regions of California and help inform decision makers about flood management policies and investments in the coming decades. This Flood Future Report provides an overview of flood management statewide, expanding other State efforts that have been focused primarily in the Central Valley.

The Flood Future Report was developed to answer three foundational questions:

- The Problem: What are the flood threats in California?
- The Solution: What are the approaches to reduce flood risk in California?
- Recommendations: What are appropriate recommendations for managing California's flood risk?

The first step was accomplished by interviewing representatives of 142 local flood management agencies throughout the state, and asking them to define and characterize the type and location of existing and future flood threats and issues in their local area. Agencies were interviewed regarding existing flood infrastructure, planned flood management projects (including IWM projects with flood benefits), and flood management challenges and opportunities facing the agency.

Flooding in Santa Clara, 1995

As a result of the meetings with local agencies, more than 3,800 different documents related to flood management in California were collected. A review of these documents, combined with information from interviews, formed the foundation to explore approaches that address the array of flood risk management issues identified. Using this information, an analysis of exposure to flood hazards was completed to expand the understanding of the exposure threat to flooding statewide. This analysis

identified population, structures, crops, and endangered species exposed to flood hazards statewide for the 100- and 500-year (1 percent and 0.2 percent annual chance) flood events (see *Attachment D: Summary of Exposure and Infrastructure Inventory by County)*.

Once a basic understanding of the flood threats in California was attained, different approaches to flood management, including structural and nonstructural measures and IWM (see *Attachment H: Practicing Flood Management Using an Integrated Water Management Approach*), were explored. Financing and institutional strategies also were explored based on past funding and new, innovative ideas (see *Attachment I: Finance Strategies*).

Finally, an appropriate path forward to manage California's flood risk was identified by formulating technical, legislative, policy, financial, and other recommendations (see *Attachment J: Recommendations to Improve Flood Management in California*). These recommendations were synthesized from information developed as part of the SFMP Program, including suggestions from flood experts, previous flood management studies, and local agency recommendations.

1.2.2 Report Organization

This Flood Future Report contains a comprehensive look at flood hazards throughout the state, and it describes the challenges and opportunities facing flood management. This report provides information intended to inform decisions about policies and financial investments to improve public safety, foster environmental stewardship, and support economic stability. The report is supported by 10 technical memoranda presented as attachments:

- **Attachment A: References**
- **Attachment B: Glossary of Terms**
- **Attachment C: History of California Flooding.** This attachment provides a detailed history of flooding in the 10 major California Water Plan (CWP) hydrologic regions.
- **Attachment D: Summary of Exposure and Infrastructure Inventory by County (Mapbook).** This attachment is a mapbook, organized by county, that provides information on exposure to flooding, flood infrastructure, flood types present, list of major floods, and information on the planned/proposed projects.
- **Attachment E: Existing Conditions of Flood Management in California (Information Gathering Findings).** This attachment provides an overview of the information gathering effort to collect flood management information from local, State, tribal, and Federal agencies, as well as a detailed summary of the results of the information-gathering effort. The purpose of this effort was to develop a better understanding of flood risk management in California.
- **Attachment F: Flood Hazard Exposure Analysis.** This attachment describes the methodology used to identify flood hazard exposure statewide, as well as the results of the flood hazard exposure analysis. The

analysis was performed to provide insight into potential flood exposure throughout the state by California hydrologic region, county, Integrated Regional Water Management (IRWM) region, primary and secondary Sacramento-San Joaquin River Delta (Delta) zones, California state assembly and senate districts, and U.S. congressional districts.

- **Attachment G: Risk Information Inventory.** This attachment provides an understanding of flood risk information available statewide.
- **Attachment H: Practicing Flood Management Using an Integrated Water Management Approach**. This attachment provides a description of the evolution of flood management practices toward using an IWM approach, an overview of IWM, the benefits of using an IWM approach, and sample case studies of projects that have used an IWM approach.
- **Attachment I: Finance Strategies.** This attachment provides an understanding of the current status of flood management financing and the challenges that lie ahead as California develops recommendations to address flood management issues.
- **Attachment J: Recommendations to Improve Flood Management in California.** This attachment provides a detailed description of how the Flood Future Report recommendations were developed and outlines the recommendations along with other high-level challenges.

Yuba River Flooding, 1986

Information developed under the SFMP Program for the Flood Future Report can be found in various forms, which were developed for different audiences and purposes, as shown in Figure 1-3. The three specific documents are the Policy Brief, Highlights, and the Flood Future Report, including its technical attachments. The Flood Future Report is a companion report to the California Water Plan Update 2013.

The **Policy Brief** document provides a high-level summary of the key information contained in the Flood Future Report and its technical attachments. This document is meant to inform legislators, legislative staff, and agency executives.

The **Highlights** document is an Executive Summary of the Flood Future Report. The Highlights document is intended for use by legislators, legislative staff, agency executives, and the public.

The **Flood Future Report** is intended to educate and inform the public and agency staff about flood risk management. Attachments C through J of the Flood Future Report were developed to provide detailed technical information for use by agency staff and technical experts.

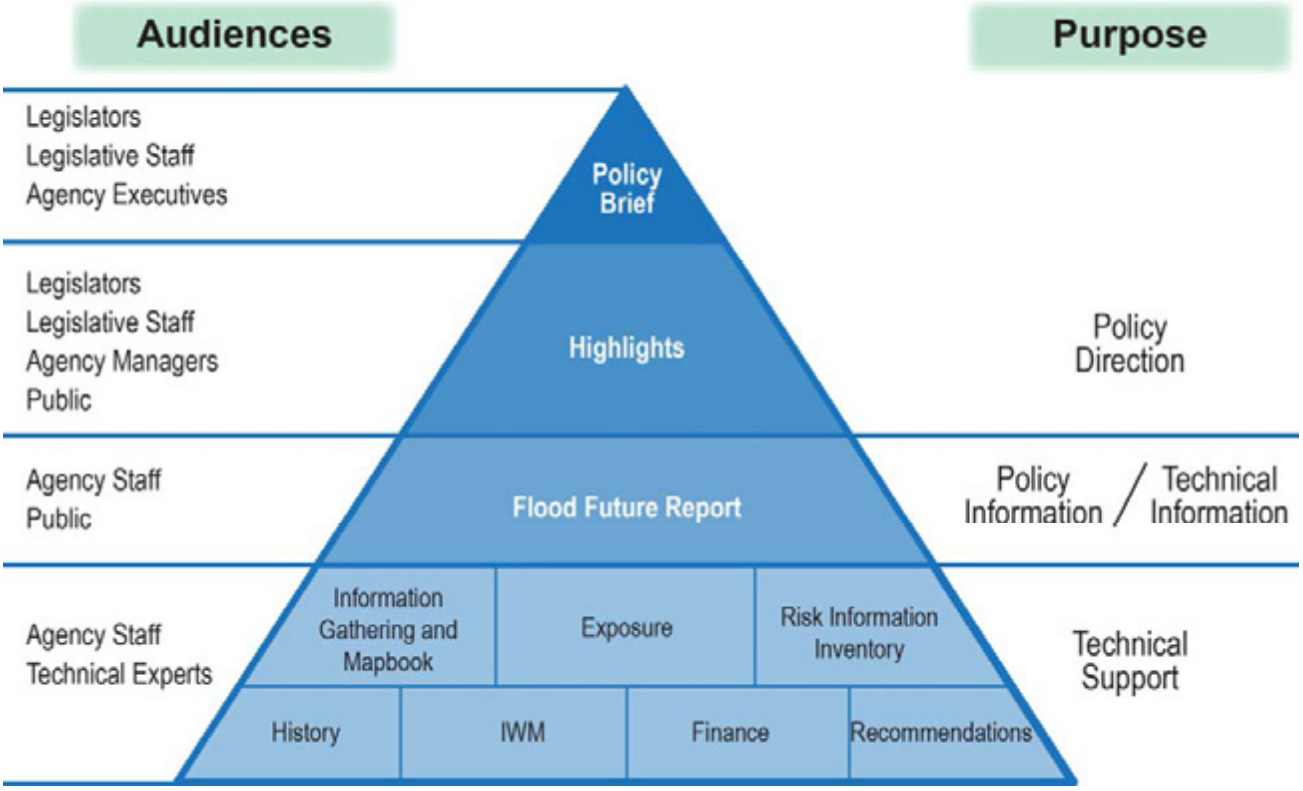

Figure 1-3. Various Documents Developed under the Statewide Flood Planning Management Program

The documents are formatted using different-colored headers to indicate the purpose of a given section. The color scheme corresponds to the following coding format:

- Introduction (light blue)
- Understanding the Situation (brown)
- The Problem (goldenrod)
- The Solution (royal blue)
- Recommendations (green)
- The Path Forward (yellow)

Appendices to an attachment were coded using a light blue to represent that they are background or supporting information.

2.0 Understanding the Situation – California is at Risk

This section provides an overview of background information to assist in understanding flood risk management and issues that can hinder effective flood risk management. Understanding flood risk in California today requires a general knowledge of the following information:

- Types of flooding that occur
- Integration of water management systems
- Flood risk management actions available
- How complex flood risk is defined and used
- Costs associated with recovery from floods

Alpine County Flooding 1997

In addition, there are a number of issues identified by local agencies that are obstacles to effective floodplain management, including:

- Inadequate flood management system integration
- Fragmented floodplain management responsibility
- Inadequate public understanding of risk and residual risk
- Unstable funding, competing land use needs, conflicting and complex permitting requirements

2.1 California is Exposed to Many Types of Flooding

Flooding is a significant statewide threat to life safety, the environment, and the economy; however, the impacts of flood events vary across the state because of the diversity in geographies, climates, and land use. Several types of flooding occur throughout California due to variations in:

- Weather and climate patterns (e.g., El Niño, La Niña, Pineapple Express, Atmospheric River)
- Hydrologic features
- Composition of soil and bedrock
- Type and density of vegetation
- Patterns of land use
- Topography

These conditions result in floods that differ in characteristics such as warning time, duration, depth, and levels of damage, depending on where, when, why, and how the flooding occurs.

The types of flooding (Figure 2-1) in California can be divided into eight categories:

- **Flash flooding** – Quickly forming floods with high-velocity flows. Often caused by stationary or slow-moving storms. Typically occurs on steep slopes and impermeable surfaces, and in areas adjacent to streams and creeks.

- **Slow rise flooding** – Gradual inundation as waterways or lakes overflow their banks. Most often caused by heavy precipitation, especially with heavy snowmelt. Typically includes riverine flooding in deep floodplains and ponding of water in low-lying urban areas, as well as gradual flooding in areas adjacent to local streams and creeks. Slow rise flooding in California is on the order of days, not weeks/months like in the U.S. Midwest on the Mississippi River system.

- **Debris-flow flooding** – Flows made up of water, liquefied mud, and debris can form and accelerate quickly, reach high velocities, and travel great distances. Commonly caused by heavy localized rainfall on burned hillsides devoid of vegetation.

- **Alluvial fan flooding** – Flows of shallow depth and high velocity, with sediment transport, along uncertain flow paths on the surface and at the toe of alluvial fans. Typically caused by localized rainstorms, often with snowmelt.

- **Coastal flooding** – Inundation at locations normally above the level of high tide. Often caused by storm surges occurring with high tide.

- **Tsunami flooding** – High-speed seismic sea waves triggered by mass movement that displaces a large volume of water. Causes include earthquakes and underwater landslides. Impact on land depends on wave height and inundation area.

- **Stormwater flooding** – Localized flooding that occurs in urbanized areas during or after a storm event. Generally, the extent of flooding is confined to a smaller area compared to other types of flooding. Usually results from clogged or overwhelmed storm drain systems that become incapable of conveying stormwater runoff efficiently to outfalls or into creeks and rivers.

- **Engineered structure failure flooding** – Flooding as a result of dam failure or levee failure presents the potential of catastrophic impact, depending on amount of water impounded and location of populated areas downstream.

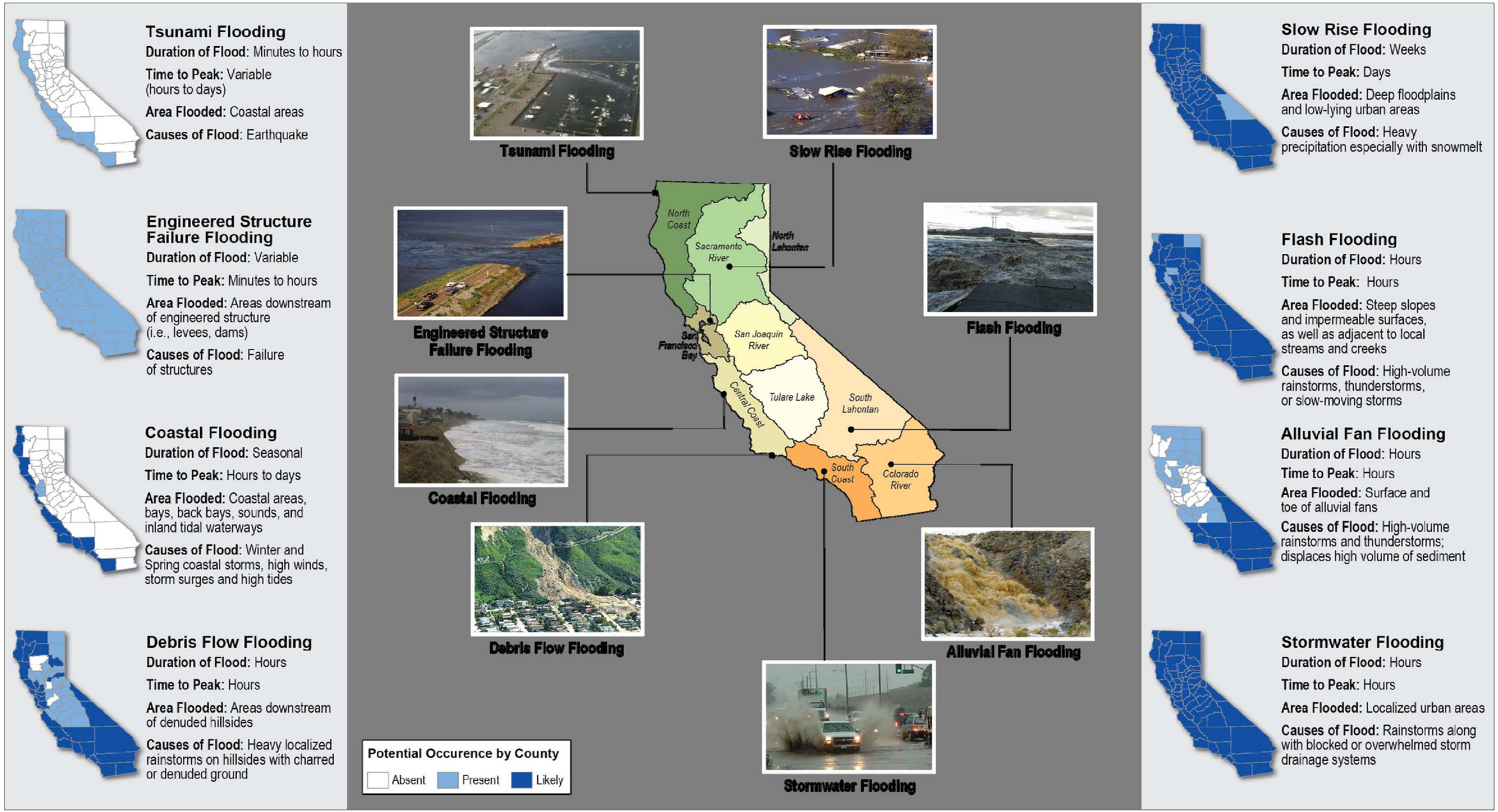

Figure 2-1. Types of Flooding in California

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All California communities are at risk of at least one of these flood types, and most California communities are vulnerable to more than one type. Even though there are common flood types, a one-size-fits-all approach to managing flood risk in California is not feasible due to the variability in population density, geography, hydrology, and climate. For example, the North Coast region of California has less population, along with mountains that meet a small coastal plain with natural riverine systems that are capable of carrying high flows from the high quantity of rainfall in the region. On the other hand, in southern California, a large population is concentrated on an expansive coastal plain with riverine systems that have low flows during most of the year but swell during infrequent major storm events. Detailed information on each flood type is provided in *Attachment C: History of California Flooding*.

Laguna Canyon Channel, February 1969

2.2 Flood Management Cannot Be Accomplished in Isolation

Historically, water supply, flood risk management, and ecosystems have been managed somewhat independently within a watershed without full system integration. However, in California, flood management, ecosystem health, and water supply are inextricably linked, as actions for one area can affect other areas. For example, dams, reservoirs, and related infrastructure are an important part of the Central Valley Flood Management System. Although the Sacramento River Flood Control Project predates the dams and reservoirs, the flood management system is enhanced by their operation. Reservoir operation is essential for control of floodwaters within the Central Valley. Reservoirs can reduce peak discharges by retaining floodwaters behind dams and making controlled releases that can be accommodated by downstream channels. The operation of dams and reservoirs largely defines the flow conditions that pass through the Central Valley State-Federal Flood Control System. Most of the dams and reservoirs, serve multiple purposes. Operating decisions are not based solely on flood management purposes; other key functions include ensuring that enough water is captured to be released later for water supply and environmental flows, as well as maintaining water surface elevations for recreation purposes.

Levee Overspray on Twitchell Island

Although the primary purpose of flood management is public safety (i.e., reduce flood risk and reduce the impacts of flooding on lives and property), flood management strategies can serve many purposes, and flood management is a key component of an IWM approach. An IWM approach promotes system flexibility and resiliency to accommodate changing conditions such as regional preferences, ecosystem needs, climate change, flood or drought events, and financing capabilities. Using an IWM approach is not a one-time activity. Long- term commitments and alignment among responsible agencies is necessary to create sustainable, affordable water resource systems that balance flood management, environmental stewardship activities, and water supply management. Therefore, the interconnection of flood risk management actions within the context of broader water resources management, along with ecosystem management, and land use planning, should be understood and recognized when crafting flood management solutions.

Additionally, solutions and their potential impacts should be evaluated from a systems perspective. An objective of the FloodSAFE initiative is to formulate strategies that will result in an economically and environmentally sustainable system of flood risk management in California. To implement this vision, we must address public safety issues while considering environmental and water resource needs.

California is facing major challenges in achieving its flood, ecosystem, and water management objectives. Placing increased pressure on the California water system are environmental considerations, institutional constraints, and aging infrastructure. Many agencies and stakeholders have roles in management of water as shown in Figure 2-2. A comprehensive, multi-stakeholder, integrated, and sustainable program for flood and water management is needed for the State to overcome twenty-first century water and flood management issues.

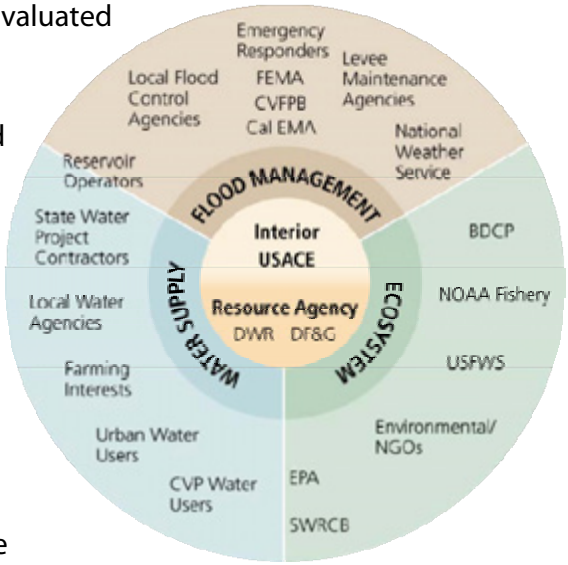


Figure 2-2. Role of Agencies in Flood, Water, and Ecosystem Management

2.3 Potential Flood Management Actions

To implement an integrated water management approach, a list of potential key management actions was identified. These actions range from policy and institutional changes to operational and physical changes and can be organized in a variety of ways. For the purposes of this report, the flood management actions were grouped into four general strategies—Nonstructural Approaches, Natural Floodplain Functions Restoration, Structural Approaches, Emergency Management, and Crosscutting Approaches. These strategies and the management actions associated with them serve as a toolkit of potential actions that local, State, and Federal agencies can use to address flood-related issues and promote IWM.

2.3.1 Nonstructural Approaches

Nonstructural approaches to flood management include **land use planning** and **floodplain management**.[2]

Land Use Planning

Land use planning employs policies and practices to limit development in flood-prone areas and encourages land uses that are compatible with floodplain functions. This can include policies and practices that restrict or prohibit development within floodplains, restrict size and placement of structures, prevent new development from causing adverse flood impacts to existing structures, encourage reduction of

Construction within the Floodplain (survey pole denotes elevation of 100-year flood event)

[2] The Water Resources Development Act of 1974 (PL 93-251) established the general policy for all Federal agencies to give planning consideration to nonstructural measures to reduce or prevent flood damage and established that the Federal government can participate in the funding.

impervious areas, require floodproofing of buildings, and encourage long-term restoration of streams and floodplains.

Floodplain Management

Floodplain management generally refers to nonstructural actions to floodplains that reduce flood damages and losses. Floodplain management actions include:

- **Floodplain Mapping and Risk Assessment –** Floodplain mapping and risk assessment serve a crucial role in identifying properties that are at a high risk of flooding. Accurate, detailed maps are required to prepare risk assessments, guide development, prepare plans for community economic growth and infrastructure, utilize the natural and beneficial function of floodplains, and reduce risk to private and public investments. The development of needed technical information includes topographic data, hydrology, and hydraulics of streams and rivers, delineation of the areas subject to inundation, assessment of properties at risk, and calculation of the probabilities of various levels of loss from floods.
- **Land Acquisitions and Easements –** Land acquisitions and easements can be used to restore or preserve natural floodplain lands and to reduce the damages from flooding by preventing urban development within floodplains. Land acquisition involves acquiring full-fee title ownership of the lands. Easements provide limited-use rights to property owned by others. Flood easements, for example, are purchased from a landowner in exchange for the perpetual right to periodically flood the property when necessary or to prohibit planting certain crops that would impede flood flows. Conservation easements can be used to reduce risk to agricultural or wildlife habitat lands from urban development. Although land acquisition and easements can be expensive, they reduce the need for structural flood improvements required to reduce flood risk.
- **Building Codes and Floodproofing –** Building codes and floodproofing include specific measures that reduce flood damage and preserve egress routes during high-water events. These codes could require floodproofing measures that increase the resilience of buildings through structural changes, elevation, or relocation.

DWR Flood Risk Notification Program Flyer, 2012

- **Retreat –** Retreat is the permanent relocation, abandonment, or demolition of buildings and other structures to allow the shoreline to advance inward unimpeded. It is used for areas subject to high coastal flooding risks, high erosion rates, or future sea level rise.
- **Flood Insurance –** Flood insurance is provided by the Federal government via the National Flood Insurance Program (NFIP) to communities that adopt and enforce an approved floodplain management ordinance to reduce

future flood risk. The NFIP enables property owners in participating communities to purchase insurance against flood losses.

- **Flood Risk Awareness (Information and Education) –** Flood risk awareness is critical because it encourages prudent floodplain management. Flood hazard information is a prerequisite for sound education in understanding potential flood risks. If the public understands the potential risks, they can make decisions to reduce their risk, increase their personal safety, and expedite recovery after floods. Effective risk awareness programs are critical to building support for funding initiatives and to building a connection to the watershed.

2.3.2 Natural Floodplain Function Restoration

This strategy recognizes that periodic flooding of undeveloped lands adjacent to rivers and streams is a natural function and can be a preferred alternative to restricting flood flows to an existing channel. The intent of restoring natural floodplain functions is to preserve and/or restore the natural ability of undeveloped floodplains to absorb, hold, and slowly release floodwaters. To permit seasonal inundation of undeveloped floodplains, some structural improvements (e.g., weirs) might be needed to constrain flooding within a defined area, along with nonstructural measures to limit development and permitted uses within those areas subject to periodic inundation. Actions that support natural floodplain and ecosystem functions include:

Red Clover Creek – Before (above) and After (below) Restoration

- **Natural Hydrologic, Geomorphic, and Ecological Processes –** Natural hydrologic, geomorphic, and ecological processes are key components of promoting natural floodplain and ecosystem functions. Human activities (including infrastructure, such as dams, levees, channel stabilization, and bank protection) have modified natural hydrological processes by changing the extent, frequency, and duration of natural floodplain inundation. These changes have disrupted natural geomorphic processes, such as sediment erosion, transport, and deposition, which normally cause channels to migrate, be cut off, and split and rejoin downstream. Restoration of these processes might be achieved through setting back levees, restoring channel alignment, removing unnatural hard points within channels, or purchasing lands or easements that are subject to inundation.
- **Quantity, Quality, and Connectivity of Native Floodplain Habitats –** Quantity, quality, and connectivity of native floodplain habitats are critical factors to promote natural floodplain and ecosystem functions. Lack of linear continuity of riverine, riparian habitats, or wildlife corridors has impacts on the movement of wildlife species among habitat patches and results in a lack of diversity, population complexity, and viability. This can

lead to native fish and wildlife becoming rare, threatened, or endangered. Floodplain habitat creation or enhancement can be accomplished by setting back levees, expanding channels or bypasses, or by removal of infrastructure that prevents flood flows from entering floodplains.

- **Invasive Species Reduction –** Invasive species can reduce the effectiveness of flood management infrastructure by decreasing channel capacity, increasing rate of sedimentation, and increasing maintenance costs. Non-native, invasive plant species often can out-compete native plants for light, space, and nutrients, further degrading habitat quality for native fish and wildlife. These changes can supersede natural plant cover, eliminate, or reduce the quality of food sources and shelter for indigenous animal species, and disrupt the food chain. Reductions in the incidence of invasive species can be achieved by defining and prioritizing invasive species of concern, mapping their occurrence, using best management practices for control of invasive species, and using native species for restoration projects.

2.3.3 Structural Approaches

Structural approaches to flood management include Flood Infrastructure, Reservoir and Floodplain Storage and Operations, and Operation and Maintenance.

Flood Infrastructure

Flood infrastructure varies significantly based on the type of flooding. Flood infrastructure can include:

Colusa Weir and Bypass – normal flow (above) and 1997 flood (below)

- **Levees and Floodwalls** – Levees and floodwalls confine flood flows by containing the waters of a stream or lake. Levees are earthen or rock berms constructed parallel to a stream or shore (or around a lake) to reduce risk from all types of flooding. Levees could be placed close to the edge of a stream or farther away from it (e.g., a setback levee). A floodwall is a structural reinforced-concrete wall designed and constructed to hold back floodwaters. Floodwalls have shallow foundations or deep foundations, depending on flood heights and soil conditions.
- **Channels and Bypasses** – Channels and bypasses convey floodwaters to prevent slow rise, flash, and debris-flow flooding. Channels can be modified by deepening and excavating the channel to increase its capacity, or lining the streambed and/or banks to increase drainage efficiency. Bypasses are structural features that divert a portion of flood flows into adjacent lands (or underground culverts) to provide additional flow-through capacity and/or to store the flows temporarily and slowly release the stored water.
- **Retention and Detention Basins –** Retention and detention basins are used to collect stormwater runoff and slowly release it at a controlled rate so that downstream areas are not flooded

or eroded. A detention basin eventually drains all of its water and remains dry between storms. Retention basins have a permanent pool of water and can improve water quality by settling sediments and attached pollutants.

- **Culverts and Pipes** – Culverts and pipes are closed conduits used to drain stormwater runoff. Culverts are used to convey streamflow through a road embankment or some other type of flow obstruction. Culverts and pipes allow stormwater to drain underground instead of through open channels and bypasses.
- **Coastal Armoring Structures and Shoreline Stabilization** – Coastal armoring structures and shoreline stabilization reduce risk in low-lying coastal areas from flooding. Coastal armoring structures typically are massive concrete or earthen structures that keep elevated water levels from flooding interior lowlands and prevent soil from sliding seaward. Shoreline stabilization reduces the amount of wave energy reaching a shore or restricts the loss of beach material to reduce shoreline erosion rates. Types of shoreline stabilization include breakwaters, groins, and natural and artificial reefs.

Crescent City Breakwall, 2012

- **Debris Mitigation Structures –** For debris and alluvial flooding, Sabo dams, debris fences, and debris basins separate large debris material in debris flows, or they contain debris flows above a specific area. Deflection berms (or training berms) can be used to deflect a debris flow or debris flood away from a development area, allowing debris to deposit in an area where it would cause minimal damage.

Reservoir and Floodplain Storage and Operations

Reservoir and floodplain storage and operations consist of:

- **Reservoir and Floodplain Storage** – Reservoir and floodplain storage provides an opportunity to regulate flood flows by reducing the magnitude of flood peaks occurring downstream. Reservoirs collect and store water behind a dam and release it after the storm event. Floodplain storage occurs when peak flows in a river are diverted to adjacent off-stream areas. Floodplain storage can occur naturally when floods overtop a bank and flow into adjacent lands, or the storage can be engineered using weirs, berms, or bypasses to direct flows onto adjacent lands.

Dominguez Gap Detention Basin and Wetlands

- **Storage Operations** – Storage operations can reduce downstream flooding by optimizing the magnitude or timing of reservoir releases, or through greater coordination of storage operations. Coordination can take the form of formal agreements among separate jurisdictions or it can simply involve participation in coordination meetings during flood emergencies.

Flood Operations Center, 2006

Operation and Maintenance

Operation and maintenance (O&M) is a crucial component of flood management. For Federally funded projects, the definition of O&M includes the local entity's financial obligation for operation, maintenance, repair, rehabilitation, and replacement (OMRR&R) the implemented project. OMRR&R is a non-Federal responsibility when local, regional, and/or State entities partner on a Federal project. References to O&M provided in this report include OMRR&R responsibilities when the project is a Federal/non-Federal partnership. O&M activities can include inspection, vegetation management, sediment removal, management of encroachments and penetrations, repair or rehabilitation of structures, or erosion repairs. Because significant flood infrastructure constructed in the early to mid-twentieth century are near or have exceeded the end of their expected service lives, adequate maintenance is critical for this flood infrastructure to continue functioning properly.

2.3.4 Flood Emergency Management

Flood emergency management includes the following activities for preparedness, response, and recovery:

- **Flood Preparedness** – Flood preparedness includes the development of plans and procedures on how to respond to a flood in advance of a flood emergency, including preparing emergency response plans, training local response personnel, designating evacuation procedures, conducting exercises to assess readiness, and developing emergency response agreements that address issues of liability and responsibility.

Flood Fighting, 2006

- **Emergency Response** – Emergency response is the aggregate of all those actions taken by responsible parties at the time of a flood emergency. Early warning of flood events through flood forecasting allows the timely notification of responsible authorities so that plans for evacuation of people and property can be implemented. Emergency response also includes flood fighting and emergency sheltering. Response begins with and could be confined to the affected local agencies or operational areas (counties). Depending upon the intensity of the event and the resources of the responders, regional, State, and Federal response might be required.
- **Post-Flood Recovery** – Recovery programs and actions include restoring utility services and public facilities, repairing flood infrastructure, draining flooded areas, removing debris, and assisting individuals, businesses, and

communities to reduce risk to lives and property. Recovery planning can include development of long-term floodplain reconstruction strategies to determine if reconstruction will be allowed in flood-prone areas. Such planning should review what building standards would be required, how the permit process for planned reconstruction could be improved, and how natural floodplains and ecosystem functions could be incorporated.

2.3.5 Crosscutting Approaches

Several management actions within Flood Management are considered to be crosscutting (i.e., they would be a part of all management actions). These crosscutting actions are permitting, policy and regulations, and finance and revenue.

Permitting

Regional and programmatic permitting methods can provide faster and better delivery of flood management activities, including O&M, repair, habitat enhancement and restoration, and minor infrastructure improvement or construction projects. Regional and programmatic permitting methods can be used to collectively manage permitting needs for multiple projects, over longer planning horizons, while consolidating mitigation and conservation efforts into larger, more viable conservation areas. This can accelerate permitting of flood system projects and lower per-unit costs versus project-by-project mitigation. Regional and programmatic permitting methods include regional Habitat Conservation Plans, Natural Community Conservation Plans, programmatic Endangered Species Act Section 7 consultations, and Regional General Permits.

Agency Coordination on Jones Tract Flood Fight, 2004

Policy and Regulations

Policies and regulations that clarify flood management roles and responsibilities for local, regional, State, and Federal agencies can help improve coordination across the large number of agencies and entities involved in Flood Management. Multiple jurisdictional and regional partnerships can be encouraged for flood planning and flood management activities, including permitting, financing, O&M, repair, and restoration.

Finance and Revenue

Several finance and revenue strategies can increase the ability to fund flood management projects. Aligning flood management projects with other existing or planned projects (such as roads or highways) leverages funding from different agencies and jurisdictions to help accomplish objectives. Consolidating projects on a regional or watershed level can also improve cost effectiveness and financial feasibility by pooling resources.

2.4 Flood Risk is Complex

Flood risk is the likelihood of adverse economic and life-safety consequences from flood inundation.

Managing flood risk includes managing floodwater (keeping floodwater away from people), managing floodplain resources (keeping people and assets out of the path of floodwater), and protecting and restoring natural ecosystems. Flood risk is a complex subject that often is misunderstood due to the terms that are used to describe it. Also, different agencies use different methods to calculate flood risk. This section of the report provides basic information on flood risk, as well as how different agencies describe and use flood risk information.

2.4.1 Flood Risk Basics

Floods can be caused by bodies of water that leave their boundaries due to heavy rainfall; dams, levees, or other engineered structures failing; or extreme wet-weather patterns. Historically, the most dangerous storms in California have been extreme events resulting from weather patterns known as Atmospheric Rivers or the Pineapple Express (warm heavy storms that strike in winter, producing intense rainfall over large areas). When these storms fall on existing snowpack, flooding can be exacerbated.

Engineers, scientists, and floodplain managers define **flood risk** as the likelihood of consequences (damages) from flood inundation, including both economic and life-safety consequences. Flood risk is not simply the loss of life or damage incurred due to a single catastrophic event. Rather, flood risk characterizes the likelihood of adverse consequences for the entire range of flood events for a given impact area.

Several factors influence flood risk, including storm frequency, development in floodplains, and O&M of flood infrastructure. For example, any storm can cause flood damage, but large storms (although infrequent) can have disastrous consequences to entire regions. Although the 500-year and 100-year flood events are a simple description of the frequency of flooding, a complete flood risk analysis requires additional components. Flood risk can be thought of as a function of five components, as shown in Figure 2-3.

Flood risk is commonly described for insurance and planning purposes using the following two flood event levels:

500-Year Flood is a shorthand expression for a flood that has a 1-in-500 probability of occurring in any given year. This also is expressed as the 0.2 percent annual chance flood.

100-Year Flood has a 1-in-100 (or 1 percent) probability of occurring in any given year.

These flood event levels indicate a percentage of probability and severity. It does not mean that such a flood would happen only every 100 or 500 years.

How often does a 100-year (1 percent chance) flood event occur?

Although a 100-year flood sounds remote, over the lifespan of an average 30-year mortgage, a home located within the 100-year floodplain has a 26 percent chance of being inundated. This same home has less than a 1 percent chance of fire damage during the same period. What is more significant is if a house is in a 10-year flood area, it is almost certain to see a 10-year flood (96 percent chance) in the same 30-year mortgage cycle. In many areas the difference in flood heights between a 10-year and a 100-year event is less than 1 foot. The chart below shows flood frequency during a 30-year mortgage.

Flood Frequency Chart

Flood Frequency (years)	Chance of Flooding in any Given Year	Percent Chance of Flooding During a 30-year Mortgage
10	10 out of 100 (10%)	96
50	2 out of 100 (2%)	46
100	1 out of 100 (1 %)	26
500	0.2 out of 100 (0.2%)	6

Source: USACE 2010

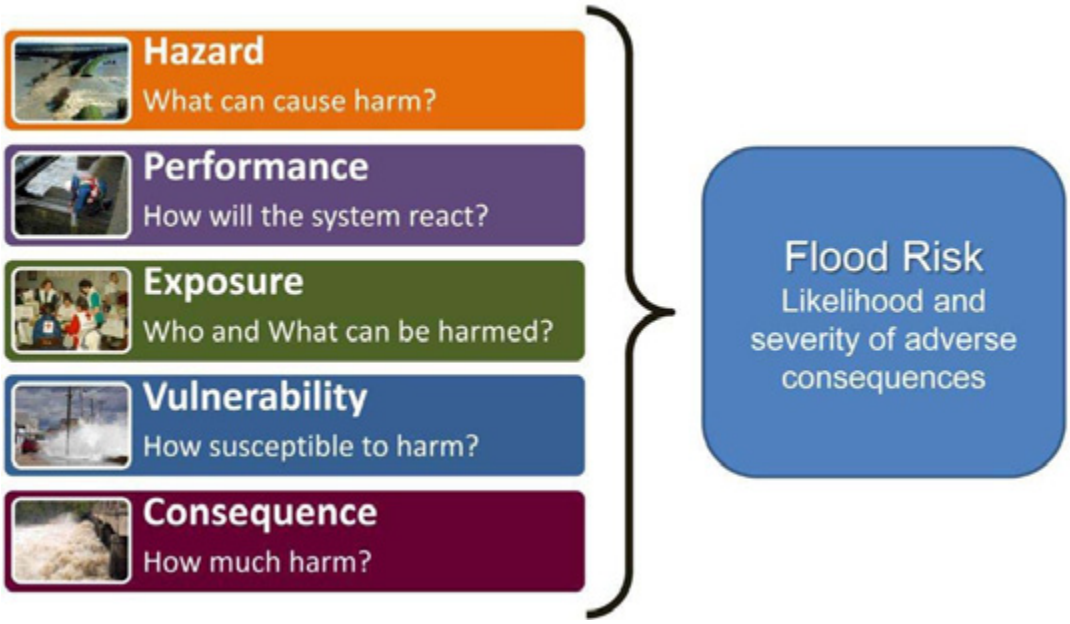


Figure 2-3. Flood Risk Definition

The computation of risk takes into account the probability of floods of various magnitudes occurring, the performance of levees and other flood management infrastructure, the exposure of property and people to the hazard, the vulnerability of property and people to the hazard, and the consequences of exposure. Detailed information on flood risk components can be found in *Attachment F: Flood Hazard Exposure Analysis*. Once computed, "flood risk" can be used to effectively plan budgets for O&M, and to establish project priorities for local, State, and Federal agencies.

2.4.2 Competing and Conflicting Terminology

The NFIP is a Federal program created by the U.S. Congress to mitigate future flood losses nationwide.

Local, State, and Federal agencies frequently use competing and conflicting terminology and assessment methodologies for flood risk, as outlined previously in Textbox 1-2. A DWR or USACE planning study requires an analysis that includes all five flood risk components. In contrast, FEMA uses only an analysis of flood hazard to describe flood risk for the NFIP. Local agencies typically describe flood risk in terms of compliance with the NFIP; however, some larger agencies describe and calculate risk using methodologies that incorporate other components, such as exposure and vulnerability. The following section describes different approaches typically used to assess flood risk.

DWR and USACE Approaches

For a DWR or USACE planning study that is intended to identify and evaluate specific flood management measures (including type, location, and dimensions), a detailed risk analysis is required. A detailed flood risk analysis would evaluate the consequences of a full range of possible flood hazards, which includes considering the likelihood of the flooding, the performance of existing or proposed actions and measures, current and future exposure of people and property to flooding, and the vulnerability of people and property.

The DWR method for developing risk assessments is described in two documents:

- DWR, *Economic Analysis Guidebook*, January 2008
- DWR, *Draft Economic Analysis Guidelines Flood Risk Management*, May 2010

These DWR documents are available for downloading from the Internet at http://www.water.ca.gov/economics/guidance.cfm.

These methods are used primarily for Early Implementation Projects funded under Propositions 1E and 84. The DWR approach is based upon the USACE method for risk assessments.

The USACE method for developing risk assessments is described in the following reference documents:

- Engineer Regulation (ER) 1105-2-100, *Planning Guidance Notebook*, April 22, 2000
- Engineer Manual (EM) 1110-2-1619, *Risk-Based Analysis for Flood Damage Reduction Studies*, August 1, 1996
- ER 1105-2-101, *Risk Analysis for Flood Damage Reduction Studies*, January 3, 2006

These USACE documents are available for downloading from the Internet at http://usace.army.mil/publications/.

FEMA Flood Hazard Approach

FEMA describes flood hazard with a Flood Insurance Study (FIS). The FIS uses statistical data for river flow, storm tides, hydrologic/hydraulic analyses, and surveys of rainfall and topography to create flood hazard maps. These areas are identified on Flood Insurance Rate Maps (FIRMs).

FIRMs show Special Flood Hazard Areas (SFHAs), which are areas subject to inundation from a flood that has a 1 percent chance of being equaled or exceeded in a given year. This is known as the 1 percent annual chance flood event, the 100-year flood event, or base flood, and is used as the basis of the NFIP. The NFIP is a Federal program created by the U.S. Congress to mitigate future flood losses nationwide. The NFIP requires local communities to enforce building and zoning ordinances in exchange for access to affordable, Federally funded, flood insurance for property owners.

The flood hazard information presented in the FIRMs results from engineering studies, which are reviewed for compliance with FEMA guidelines and approved by FEMA.

2.4.3 Residual Flood Risk

Residual risk is the likelihood of damage or other adverse consequence remaining after flood management actions are taken. For example, if a new dam were constructed, that reservoir would reduce the risk to people and property in the floodplain. The dam and reservoir would be designed and built with a specific storage capacity—a capacity that could be exceeded, albeit rarely. Once that capacity is exceeded by an inflow volume greater than the storage capacity of the reservoir, the dam will make uncontrolled releases that could exceed the downstream channel capacity and result in flooding. Water could overflow the channel, inundating property and causing damage in the floodplain. Exceedance of reservoir capacity in this example may cause loss of life, and the likelihood of loss of life (based on past events) is the residual life-safety risk. The flooding is not caused by failure of the designed flood infrastructure but by exceedance of design parameters.

Residual Risk – Example of Dam Overtopping

Residual Risk – Example of Levee System Failure

In addition to capacity exceedance, residual risk is a consequence of imperfect performance or failure of flood management measures. For example, a number of levees were built prior to modern construction standards and might have been built using what are now considered substandard

construction materials or might have been built on poor foundation conditions, which can lead to seepage of water through and/or under the levee core, among other issues. This seepage can result in a levee break or failure.

For reasons such as these, areas behind levees have a certain residual risk.

A floodplain is never fully protected with 100 percent certainty; at best, risk can only be reduced.

2.5 Flood Recovery Costs Are High

Although catastrophic flooding events have been infrequent, history has shown that when they do occur losses are huge. The devastation from major storms such as Superstorm Sandy, Hurricanes Katrina and Rita, and many others serve as a reminder that preventing the consequences of disasters is a more cost-effective and responsible strategy than recovering from disasters.

Loss of function is a term to describe the broader regional economic impacts (or ripple effects) caused by direct flood damages, such as the costs resulting from re-routing traffic, closing businesses, or affecting services such as water treatment, utilities, communications, energy generation, and health care.

In 1997, a series of tropical storms hit northern California, spawning widespread flooding. In all, flood damages totaled approximately $2 billion, with more than 23,000 homes and businesses damaged, as well as roads, bridges, and flood management infrastructure (FEMA, 2011; DWR, 2011). Approximately 120,000 people were evacuated from their homes. Looking outside California at flood damages caused by Hurricane Katrina, direct property damages were estimated at $96 billion to $125 billion. Estimates put the total economic loss from Katrina as high as $250 billion, taking into account the disruption of economic activity (*Swiss Re*, 2007).

The State of California, the USACE, and local agencies have taken significant steps to reduce flood risks and the consequences of flooding in California. Flood management officials agree that these improvements prevented recent flood events from becoming major flood disasters, but much more remains to be done.

More than 7 million people and $580 billion in assets are directly exposed to the hazards of flooding within the 500-year floodplain in California. In addition to the potentially huge direct impacts to public health and safety, floods can cause broader social and economic disruptions (loss of function) to regional economies, the State's economy, and the national economy. In addition, large floods can adversely affect ecosystem functions.

Impacts from flooding to transportation systems can be substantial. The interruption to the movement of people, goods, and services could last from days to months following a large flood event. Urban communities could experience delays in commuting, having to find alternative routes, and rural communities could have their sole transportation corridor cut off because of the flooding, isolating the community. Critical facilities, such as hospitals, nursing homes, police and fire stations, and other government buildings, could be isolated by the flood, requiring

additional resources to maintain their operations. Evacuations to other facilities and buildings outside the flooded area could be required.

Health and human services could be affected during floods, with a limited availability of potable water to the community being a primary concern. Temporary closures of medical clinics, schools, welfare services, and other governmental services could affect a much larger portion of the community than those areas directly flooded. A flood could overload wastewater treatment facilities, causing a release of untreated sewage into rivers, bays, or the ocean, or possibly backing up the sewer system to the street level.

The Sacramento-San Joaquin Delta (Delta) region provides some portion of the water supply to two-thirds of the population of California. If flood damages in the Delta caused by multiple levee failures disrupted the delivery of water for a significant period of time, the economic impacts would be substantial (tens of billions of dollars), with impacts reaching far beyond California. Delta water disruptions would also threaten about 3 million acres of productive farmland.

Agriculture is a critical sector of the State economy that provides and supports reliable, affordable food and fiber production, both domestically and on a global scale. Agricultural and associated processing industries and services account for a considerable portion of local employment in many rural counties. More than 2.8 million acres of agricultural lands are exposed within the 500-year floodplains in California. Because California leads the nation in agricultural cash receipts, disruptions caused by flooding can have national and international economic repercussions (USDA, 2012).

During the response to a flood, emergency services are critical, such as limiting access to affected areas, routing people away from the flood, protecting against looting and vandalism, providing emergency medical care, evacuating trapped residents, flood fighting, and other services. In major floods, the emergency response capabilities and/or infrastructure of a community can be overwhelmed; outside assistance requires the allocation of resources from areas not affected by the flood.

Ecosystem functions could also be adversely affected, depending upon the magnitude and duration of the flood event, resulting in temporary displacement, or permanent destruction of affected flora and fauna habitats, including habitat for endangered species. In the case of catastrophic flooding, or flooding resulting from structural failures (such as dams and levees), riparian ecosystem functioning can be adversely affected over both short and long terms, and perhaps permanently.

The cost of recovering from flood disasters is indeed high—to people, to the economy, and to the environment. Investment must be made now to help prevent flood disasters and to reduce the impacts of flooding, or Californians will spend billions more—and face the consequences of loss of life, livelihoods, and ecosystems—to recover from inevitable flooding.

Sandbag Line Northern California, 1997

2.6 Local Agencies Speak Out

More than 140 public agencies responsible for flood management were interviewed for the Flood Future Report. A description of the information gathering process is provided in Textbox 2-1 and the results are discussed in *Attachment E: Existing Conditions of Flood Management in California (Information Gathering Findings)*. This research effort included soliciting information from local, State, and Federal agencies throughout California. Information gathered from the agencies included insights on opportunities and challenges related to infrastructure, financing, flood management policy, and IWM. More than 350 opportunities and challenges were identified from this research effort.

A review of these opportunities and challenges revealed a number of recurring themes from the agencies, large and small as well as rural and urban. For example, agencies expressed frustration with trying to satisfy contradictory regulations while complying with permit requirements. Another example of a common concern facing agencies is availability of funding for O&M. Other research findings included:

- **Different methodologies and inadequate data make risk assessment complex and costly to complete**. Almost one-half of the information gathering interviews included discussions on the need to improve science and tools. These tools include increased stream gauging and monitoring of meteorological and hydrologic data for flood forecasting, tools to forecast changes in sea level, improved models, advanced mapping technologies, and enhancements to risk-assessment tools.
- **Public understanding of flood risk is inadequate.** If residents are even aware that they live or work in a flood-prone area, they usually do not understand that flood management infrastructure do not provide 100 percent protection for public safety.
- **Emergency preparedness and response do not receive necessary funding in all regions in the state.** Residents depend on first responders to have the personnel, expertise, and equipment necessary to do their jobs, especially during community-wide disasters. In several areas of the state, flood infrastructure is maintained or improved only after a major flood results in significant damage. Agencies want to see a proactive/preventive approach to flood management for environmental protection and cost-saving reasons. In addition, some rural communities suggested that the NFIP needs modifications for non-urban areas because land use decisions may not adequately prioritize public safety. Uninformed residents and decision makers can make choices that put people and property at increased risk. Multiple agencies discussed the need for improvements in the

coordination and understanding about how land use decisions affect public safety.

- **Flood management projects are not prioritized from a systemwide or multibenefit perspective.** State and Federal flood management funding has traditionally been provided to narrow-benefit, local projects. Several participants recommended improving IRWM Plans and grant processes specifically to support flood management while including them in regional planning and solutions. Comprehensive, regional, multipurpose planning will ensure that a full range of possible approaches is considered.
- **Flood management responsibility is fragmented.** Responsibilities for planning, administering, financing, and maintaining flood management infrastructure and emergency response programs are usually spread among multiple agencies. More than 80 percent of the information gathering interviews involved discussions about the need for improved coordination between agencies that have flood management responsibilities.
- **Delayed permit approvals and complex permit requirements are obstacles to reduction in flood risks.** Many agencies wait years for permits, resulting in poorly maintained projects and missed funding opportunities for new projects. The interviews with almost all local agencies included discussions regarding the need for better coordination and alignment of permitting requirements among the regulatory agencies. The environmental regulatory process has become so costly that agencies, large and small, have been unable to accomplish tasks.
- **Lack of reliable, sustained funding puts California at significant risk.** Inadequate funding for flood management maintenance, operations, and improvements makes reductions in flood risk difficult or impossible for many local agencies. More than 80 percent of the information gathering interviews included discussions about the need for sustainable project and O&M financing for flood management.

Flood Damage to Highway in Inyo County

Flood Damage to San Dimas Canyon Road

Textbox 2-1: Information Gathering Effort

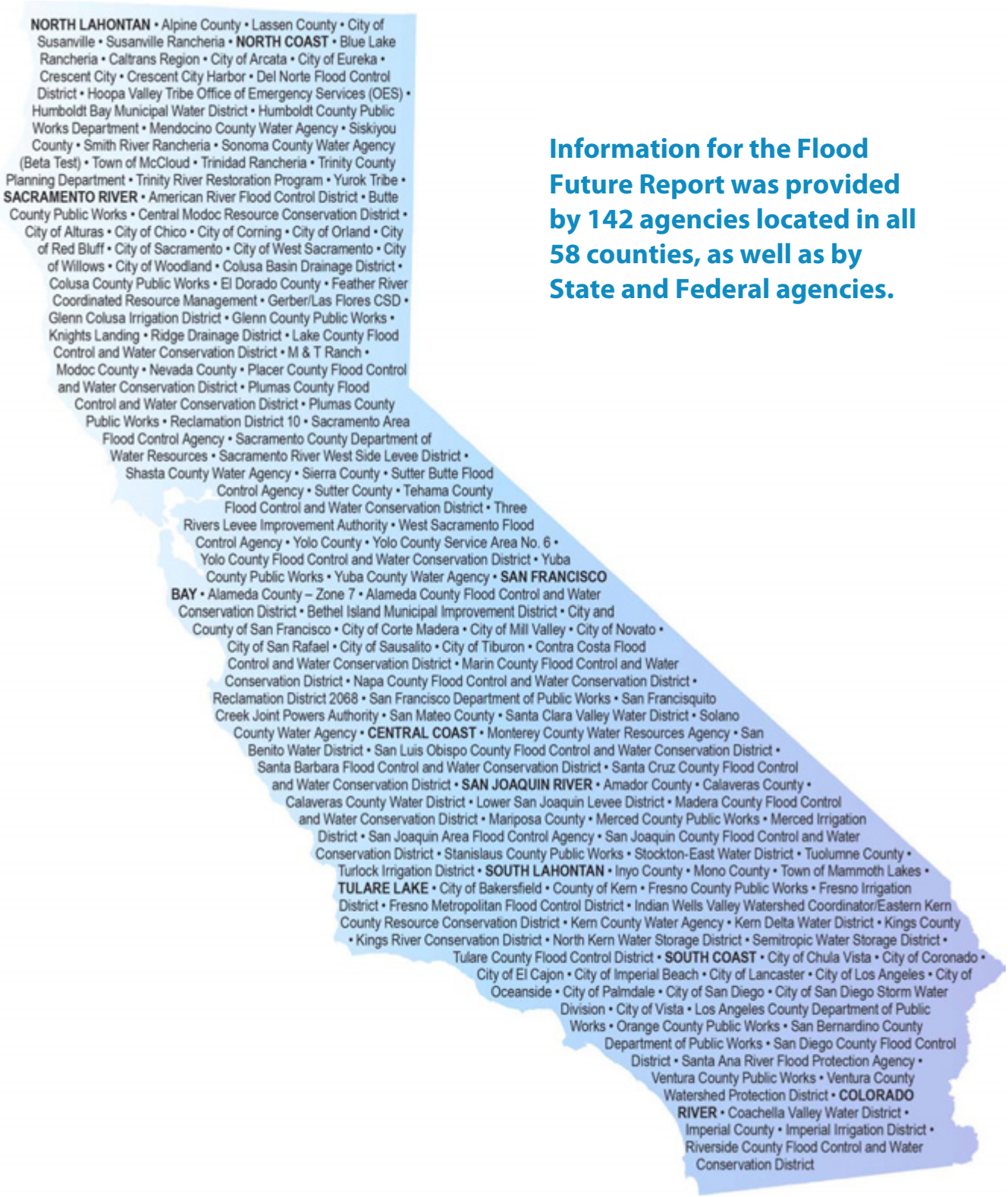
The information gathering effort was accomplished in three stages:

- **Stage 1:** Collection and analysis of existing information from DWR and USACE archives
- **Stage 2:** Outreach to targeted Federal, State, Tribal, and local entities
- **Stage 3:** Statewide information gathering, including a beta test of three counties (Sonoma, San Bernardino, and Santa Clara) with information sorting and categorization

To achieve the SFMP objective of incorporating input from local agencies across the state, the information gathering teams contacted each county in the state. Each team conducted one in-person meeting, gathered information, and performed follow-up data gathering, in some regions a follow-up meeting was necessary. Additionally, local agencies were given opportunities to review data, maps, and technical memorandums.

Products of the information gathering effort included:

- List of flood agency types and governance structures
- Inventory of risk-relevant information, including USACE risk studies
- Database of information gathered from local, State, and Federal agencies (risk, financial, infrastructure, flood history, and photographs)
- Summary of NFIP costs by hydrologic region
- Infrastructure Information database (Geographic Information System [GIS] and hardcopy)
- List of dams and reservoirs
- List of historical flood events
- List of local planned or proposed flood management projects including IWM projects
- List of USACE proposed flood management projects
- List of opportunities and challenges for flood management
- Current and projected O&M budgets (where provided)



Information for the Flood Future Report was provided by 142 agencies located in all 58 counties, as well as by State and Federal agencies.

Figure 2-4. SFMP Participating Flood Management Agencies

In Figure 2-4, California's 10 hydrologic regions are identified in bold text, followed by a list of agencies from that region who participated in SFMP interviews.

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3.0 The Problem – Lives and Property are at Risk

3.1 California is at Risk for Catastrophic Flooding

In California, more than 7 million people and over $580 billion in assets are exposed to the hazards of flooding within the 500-year floodplains. Even with a history of continuing investment and action by local, State, and Federal flood management agencies, flood risks exist in every California county. Flood exposure in California is significant, as show by the following facts:

- One in five Californians lives (i.e., is in an area exposed to flood risk) within a 500-year floodplain.
- Flooding in California has resulted in the loss of hundreds of lives and billions of dollars in damages.
- Flooding occurs in all parts of California.
- California's diverse geography contributes to the state's significant flood risk. In many California regions, peak flows – the largest volume of water flowing per second through a water system – can occur in a very short timeframe.
- The number of flood insurance policyholders in California has almost tripled since 1982, in part because of the increase in the number of structures located in floodplains and other factors (FEMA, NFIP, BureauNET, 2012).

These facts about flood exposure in California were developed during the flood hazard exposure analysis as part of the Flood Future Report. Textbox 3-1 provides a summary of the assumptions and the process used to perform the analysis. This section of the report will summarize the results of the exposure analysis. Detailed information about the analysis and analysis results are provided in *Attachment F: Flood Hazard Exposure Analysis*.

Northern California Flooding, 1997

Textbox 3-1: Flood Hazard Exposure Analysis

One of the goals of the Flood Future Report was to perform a statewide risk analysis; however, data and information were not available for this analysis. The analytical method used by the study team for assessing exposure to flood hazard is consistent with—but narrower in scope than—the method used for detailed flood risk analysis. Despite certain simplifications, the analysis of exposure to flood hazard is appropriate for this study for the following reasons:

- It provides information on potential consequences of flooding throughout the state in a consistent, systematic, repeatable manner.
- It makes use of flood hazard and exposure information from a variety of reliable, reviewed sources, including DWR, USACE, FEMA, and local agencies.
- It is aligned with, although not identical to, the risk analysis completed for the Central Valley Flood Protection Plan (CVFPP) project.
- It lays a firm foundation for future, more detailed, risk analyses.

This study provides the first steps in an efficient allocation of resources aimed at identifying and prioritizing flood management efforts.

The SFMP flood hazard exposure analysis method uses existing Geographic Information System (GIS) data to identify the population, structures, facilities, and crops located within FEMA-designated 100-year and 500-year floodplains (where available), draft 2012 CVFPP floodplains, or other best available mapping. Quantities of structures and crops exposed within the floodplain are estimated using information in the Hazards United States (HAZUS) and ParcelQuest databases. Population data were obtained from the U.S. Census and HAZUS databases. The method and data (specifically the 2000 Census) used in the flood hazard exposure analysis are designed to be consistent with flood risk analyses that were performed for the CVFPP. This analysis provides a high-level description of statewide exposure to flood hazard. Results from the flood hazard exposure analysis are presented for different analysis regions, including:

- California Water Plan (CWP) hydrologic regions
- Counties
- Legislative and congressional districts
- Sacramento-San Joaquin Delta (Delta) zones
- Integrated Regional Water Management regions

This attachment also qualitatively describes loss of function and how future uncertainties (i.e., population, land use, climate change) could impact flood hazard exposure in California. More information about the flood hazard exposure analysis can be found in *Attachment F: Flood Hazard Exposure Analysis.*

3.2 One in Five Californians Lives in a Floodplain

Flood hazard exposure is distributed throughout the state, with all counties having some level of exposure. Table 3-1 shows the population exposed to flood hazard by hydrologic region for the 100-year and 500-year floodplains. The South Coast Hydrologic Region has the largest population exposed, with more than 250,000 residents within the 100-year floodplain and more than 3 million people within the 500-year floodplains. More than 60 percent of the California population exposed to flood risk lives in two hydrologic regions –San Francisco Bay and South Coast, as shown in Figure 3-1. There also is significant flood risk in the Central Valley (more than 25 percent of the statewide exposure within in 500-year floodplains).

Table 3-1. Population Exposed to Flooding by Hydrologic Region

Hydrologic Region	100-year Floodplains		500-year Floodplains	
	Population Exposed	Percentage Exposed*	Population Exposed	Percentage Exposed*
Central Coast	90,000	6	430,000	30
Colorado River	30,000	5	230,000	38
North Coast	30,000	5	40,000	6
North Lahontan	4,000	4	4,000	4
Sacramento River	200,000	8	930,000	36
San Francisco Bay	360,000	6	1,040,000	17
San Joaquin River	160,000	9	540,000	31
South Coast	390,000	2	3,410,000	19
South Lahontan	20,000	3	150,000	21
Tulare Lake	130,000	7	500,000	27
TOTAL	1,414,000	N/A	7,274,000	N/A

Note: *The Percentage Exposed applies to the population in each specific hydrologic region; therefore, the sum of all regions does not total 100%.

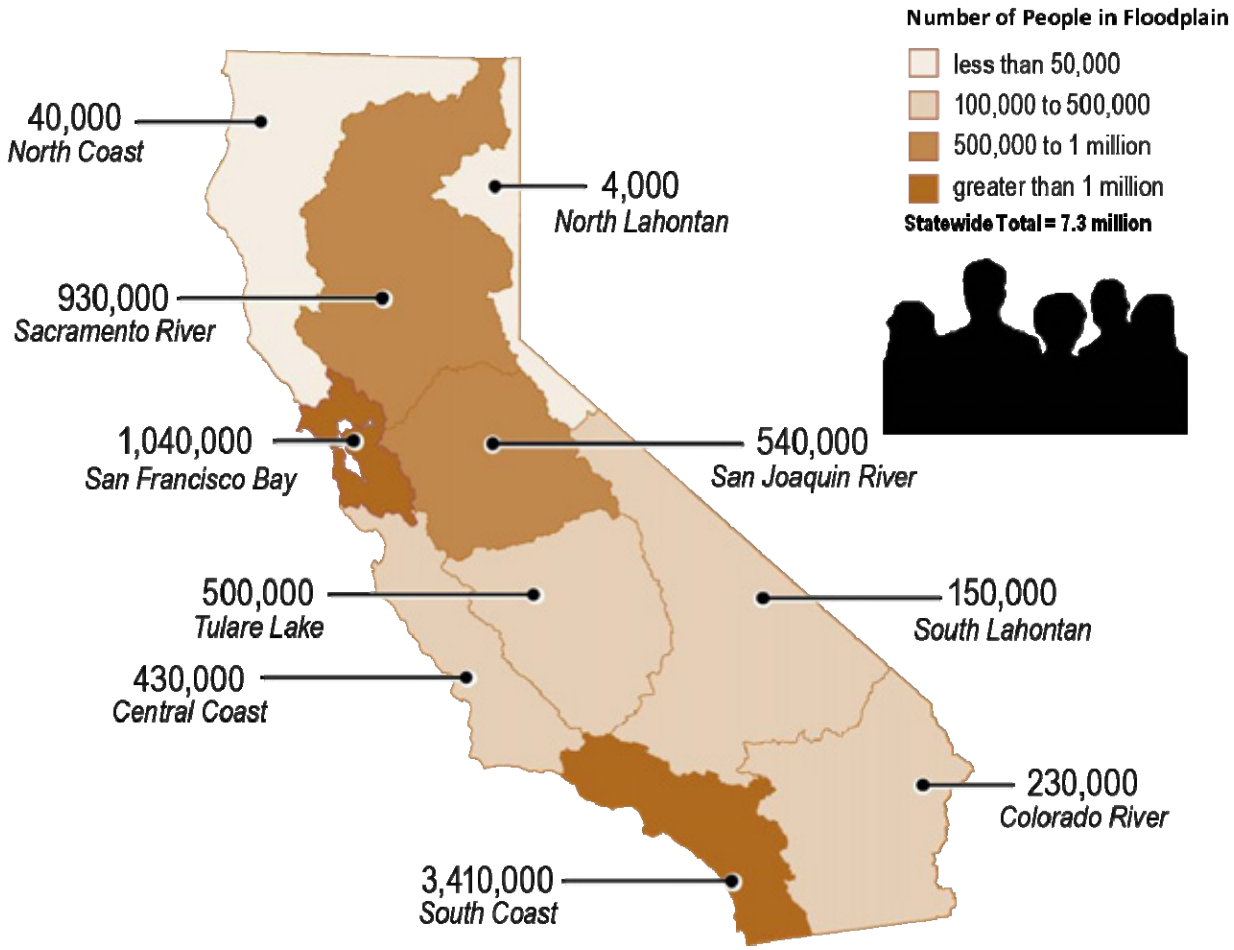


Figure 3-1. Population Exposed to Flooding within the 500-year Floodplain in California by Hydrologic Region

At a county level, Orange, San Mateo, and Santa Clara counties have the largest populations exposed within the 100-year floodplains, and Los Angeles, Orange, and Santa Clara counties have the largest populations exposed within the 500-year floodplains, as shown in Figure 3-2. More than 25 percent of the residents living in Colusa, Merced, Yolo, and Yuba counties reside within the 100-year floodplains. Los Angeles, Orange, and Santa Clara counties have over 60 percent of their populations exposed within the 500 year floodplains. San Joaquin, Sutter, and Yuba counties have over 60 percent of their populations exposed within the 500-year floodplains, as shown in Figure 3-3.

These numbers are likely to continue to increase due to population growth and development within floodplains. Population increased 10 percent in California between 2000 and 2010 and is projected by the CWP to increase between 30 percent and 106 percent by 2050.

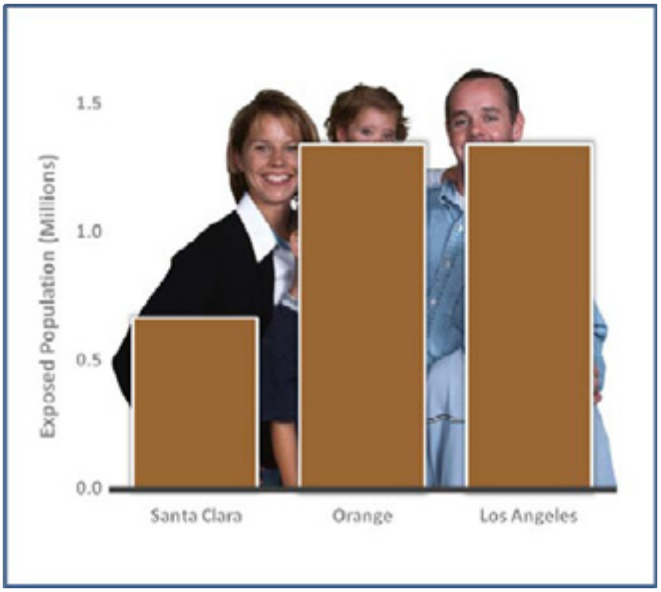


Figure 3-2. Counties with Largest Population Exposed within the 500-year Floodplains

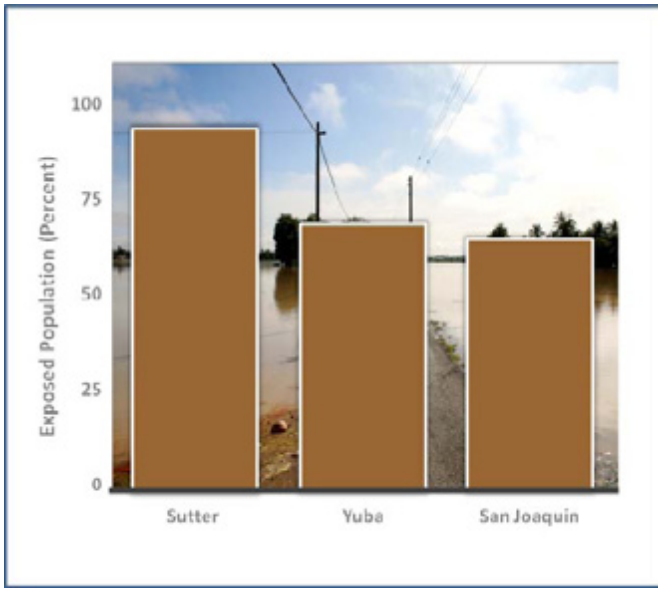


Figure 3-3. Counties with Highest Percentage of Population Exposed within the 500-year Floodplains

3.3 $575 Billion in Structures are at Risk

Property and assets are exposed to flood hazards in all regions of California. The largest numbers of facilities and structures exposed to flooding in California are in the South Coast and San Francisco Bay hydrologic regions, as shown in Figure 3-4. San Francisco Bay Hydrologic Region has the highest value of structures and contents exposed within the 100-year floodplain with almost $50 billion, and the South Coast Hydrologic Region has the second highest value with almost $40 billion. These two regions account for more than 60 percent of the statewide value of structures exposed within the 100-year and 500-year floodplains. Table 3-2 shows the value of structures exposed to these floodplains. The San Francisco Bay and South Coast hydrologic regions have over $130 billion and $230 billion, respectively, of structures and contents exposed within the 500-year floodplains.

More than 29 counties have over $1 billion each in structures exposed within the 100-year floodplains. Orange, San Mateo, and Santa Clara counties each have over $10 billion in structures exposed within the 100-year floodplains. Fourteen California counties have structures valued at more than $10 billion within 500-year floodplains. . The above figures are based on a high-level analysis performed using best available data.

Table 3-2. Value of Structures and their Contents Exposed to Flooding by Hydrologic Region

Hydrologic Region	100-year Floodplains		500-year Floodplains	
	$ billion	Percentage Exposed*	$ billion	Percentage Exposed*
Central Coast	10	12	40	48
Colorado River	3	9	20	61
North Coast	3	8	4	10
North Lahontan	1	11	1	11
Sacramento River	20	13	70	45
San Francisco Bay	50	13	130	34
San Joaquin River	10	10	40	40
South Coast	40	5	230	27
South Lahontan	2	5	10	27
Tulare Lake	10	12	30	37
TOTAL	$149	N/A	$575	N/A

Note: * The Percentage Exposed applies to the value of structures and their contents in each specific hydrologic region; therefore, the sum of all regions does not total 100%.

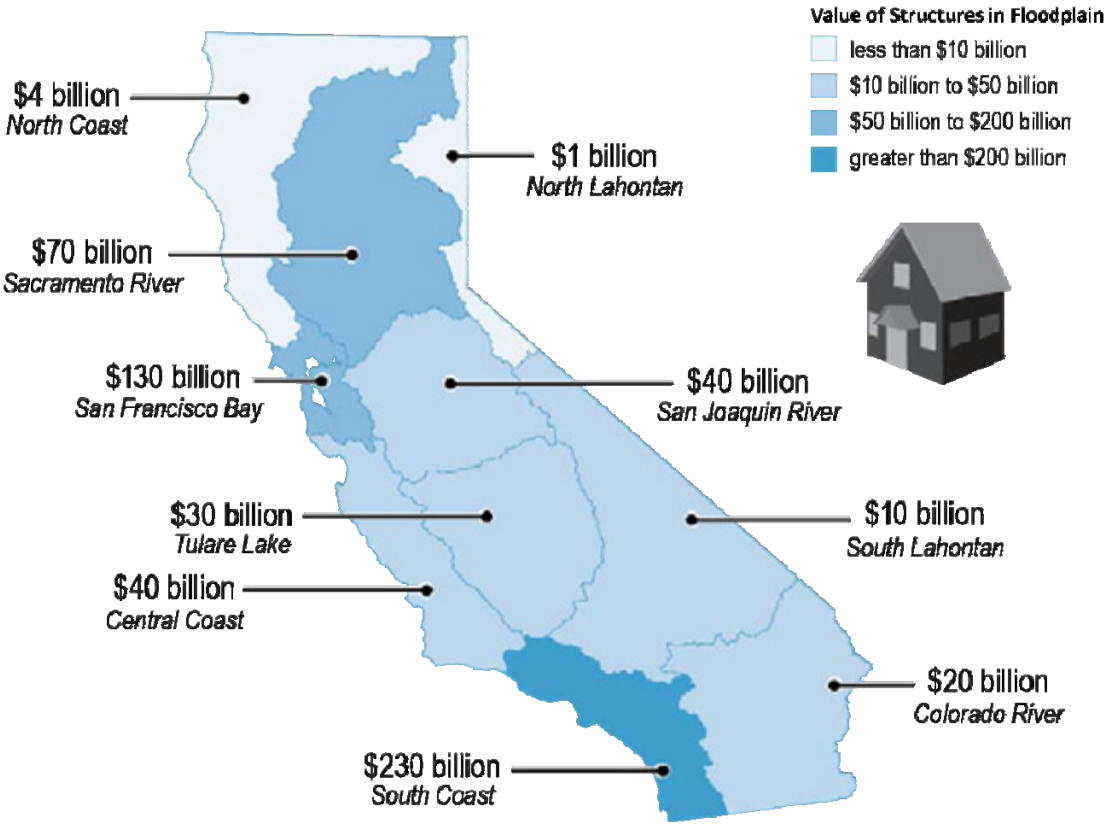


Figure 3-4. Structure Values Exposed to Flooding in California by Hydrologic Region

Forty-five percent of the statewide exposure within the 500-year floodplains in terms of value of structures occurs in just three counties— Los Angeles, Orange, and Santa Clara counties, as shown in Figure 3-5.

The $575 billion in structures exposed within the 500-year floodplains does not include the economic impact to families, communities, local businesses, and entire regions when worksites, utilities, transportation corridors, and critical public facilities are closed due to flood events. Serious flood damage in the state's large urban areas would have significant economic impacts to the region, state, and nation. And it will not take a 500-year flood event to cause significant impacts. Even a few inches of floodwater can have an expensive and disruptive impact. When flooding occurs, businesses, homes, schools, and other important structures must be vacated for proper rehabilitation, causing significant economic impacts on families and communities. The number of structures and corresponding contents exposed to flooding will likely continue to increase because of population growth and development in floodplains.

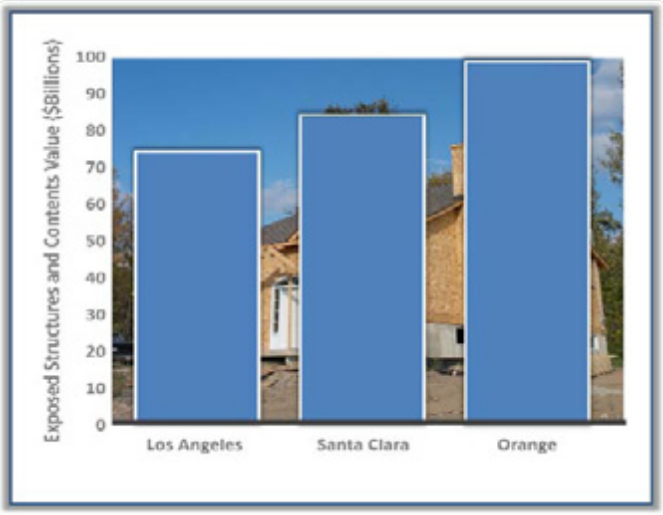


Figure 3-5. Percentage of Structures Exposed within the 500-year Floodplains

3.4 California's Agricultural Economy is at Risk

A major flood event in California has the potential to devastate regional agriculture-based economies and cause serious impacts to the State economy. Sacramento River, San Joaquin River, and Tulare Lake hydrologic regions have the greatest exposure within the 100-year floodplains. The Sacramento River Hydrologic Region has approximately 900,000 acres of farmland and $1.5 billion in crop value exposed within the 100-year floodplains. The San Joaquin River Hydrologic Region has more than 675,000 acres of farmland and $1.4 billion in crop value exposed within the 100-year floodplains. The Tulare Lake Hydrologic Region has over 801,000 acres of farmland and $1.8 billion in crop value exposed within the 100-year floodplains.

More than $7 billion in crop values are exposed within California's 500-year floodplains, and approximately 40 percent of agricultural land in the state is located in floodplains. Three hydrologic regions (Sacramento River, San Joaquin River, and Tulare Lake hydrologic

Santa Ana River Flooding near Orange, California, 1938

regions) each have more than $1 billion in agricultural crops exposed within 500-year floodplains, as shown in the summary in Figure 3-6. The Sacramento River Hydrologic Region has 1.2 million acres of farmland with a value of $1.7 billion in crops exposed within the 500-year floodplains. The San Joaquin River Hydrologic Region has nearly 900,000 acres of farmland with an estimated value of $1.9 billion in crops exposed within the 500-year floodplains. The Tulare Lake Hydrologic Region has over 990,000 acres of farmland and $2.3 billion in crop value exposed within the 500-year floodplains. Table 3-3 presents a summary for each hydrologic region showing the impacts that flooding could have on the agricultural community and economy.

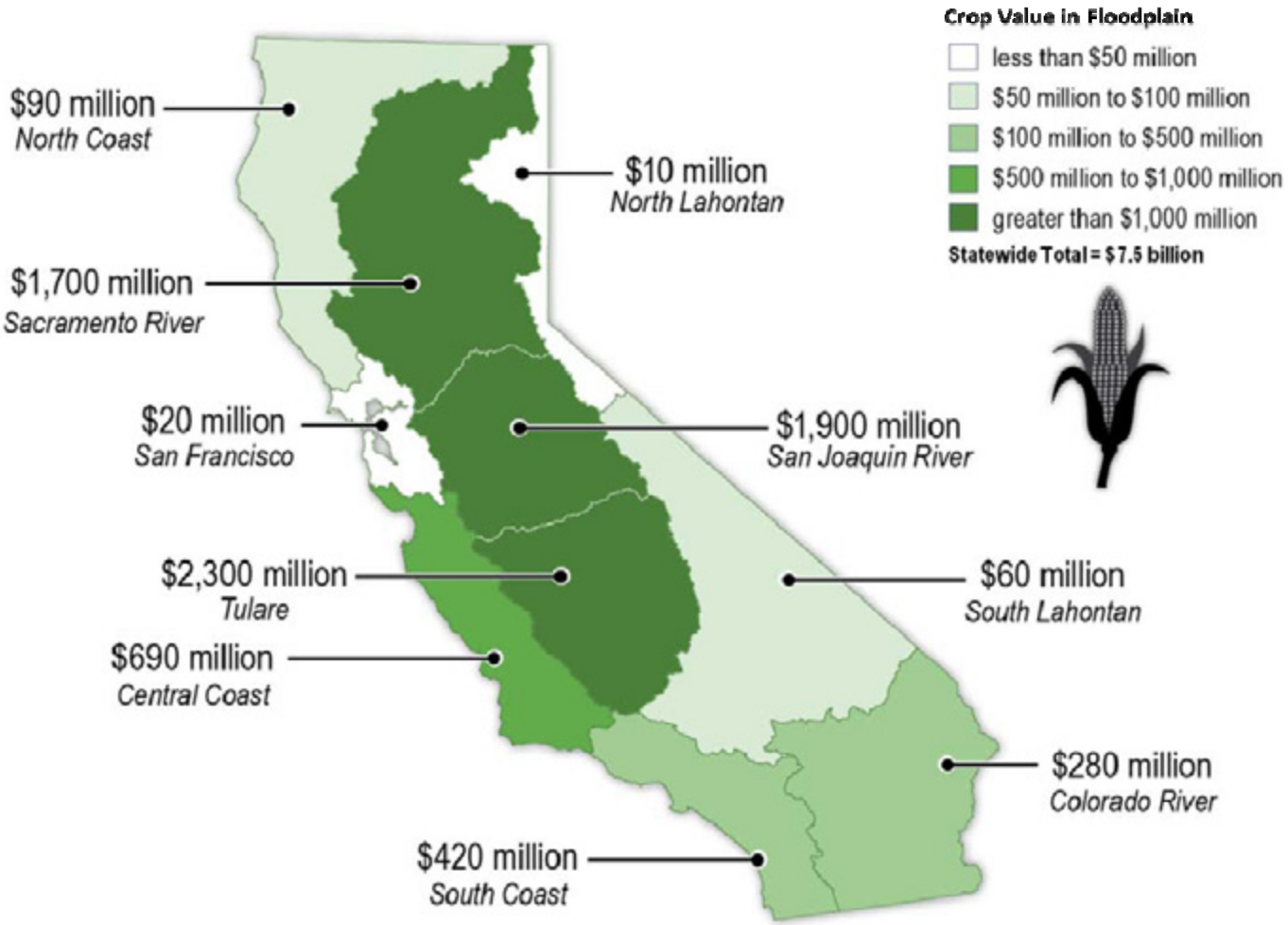


Figure 3-6. Crop Values Exposed to Flooding within the 500-Year Floodplains by Hydrologic Region

Table 3-3. Crops Exposed to Flood Hazard by Hydrologic Region

Hydrologic Region	100-year Floodplains			500-year Floodplains		
	Crop Value ($ million)	Area (acres)	Percentage Exposed (Acres)*	Crop Value ($ million)	Area (acres)	Percentage Exposed (Acres)*
Central Coast	560	123,600	18	690	146,300	21
Colorado River	150	49,000	7	280	79,100	11
North Coast	80	108,000	25	90	112,000	26
North Lahontan	10	43,000	27	10	43,000	27
Sacramento River	1,100	897,000	40	1,700	1,200,000	53
San Francisco Bay	20	33,300	23	20	44,000	31
San Joaquin River	1,400	682,000	32	1,900	879,000	41
South Coast	220	46,200	12	420	79,900	20
South Lahontan	30	41,000	16	60	72,000	28
Tulare Lake	1,800	801,000	23	2,300.00	990,000	29
TOTAL	**$5,370**	**2,824,100**	**N/A**	**$7,470.00**	**3,645,300**	**N/A**

Note:
*The Percentage Exposed applies to the crops in each specific hydrologic region; therefore, the sum of all regions does not total 100%.

Most of the agricultural exposure within the 100-year floodplains occurs in 12 counties (Butte, Fresno, Kern, Kings, Merced, Monterey, Madera, San Joaquin, Sutter, Tulare, Ventura, and Yolo), each of which has more than $100 million in exposed agricultural crops. These 12 counties make up more than 70 percent of the total value of agricultural crops in the state that are exposed within the 100-year floodplains. Agricultural exposure within the 500-year floodplains is concentrated in the same 12 counties plus 5 more counties (Imperial, Riverside, Sacramento, Solano, and Yuba), where each county has more than $100 million in exposed agricultural crops. These 17 counties contain more than 70 percent of the total value of agricultural crops in the state that are exposed within the 500-year floodplains. Seven counties— Butte, Del Norte, Humboldt, Marin, Plumas, Sutter, and Yolo—have more than 50 percent of their agricultural acreage exposed within the 100-year floodplains. These same seven counties plus the counties of Contra Costa, Colusa, Sacramento, San Joaquin, and Yuba have more than 50 percent of their agricultural acreage exposed within the 500-year floodplains. Fresno, San Joaquin, and Tulare counties have the most crop value exposed within the 500-year floodplains, as shown in Figure 3-7.

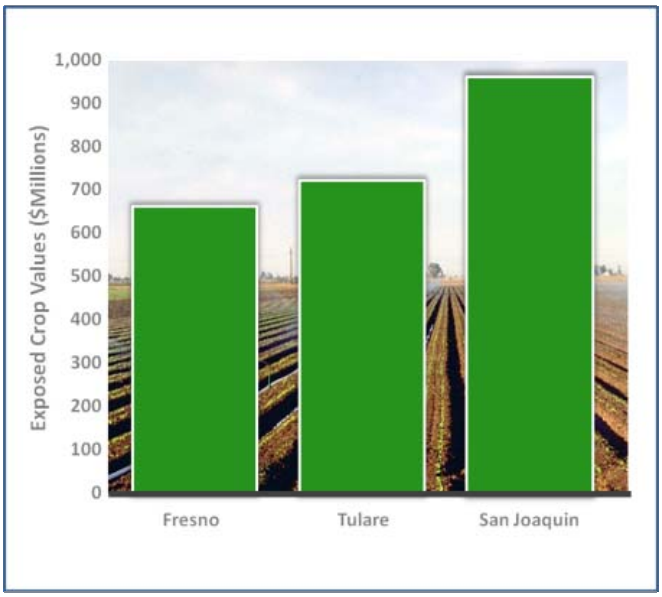


Figure 3-7. Percentage of Crops Exposed within the 500-year Floodplains

A major flood event in California could have an impact on national and international food supplies. California contributes 12 percent of the nation's total agricultural production, the most for any state, and accounts for almost $15 billion in agricultural exports worldwide. Of the 10 most

productive agricultural counties in the United States, 9 are in California, and the San Joaquin Valley is the single richest agricultural region in the world (EPA, 2012). In fact, California grows nearly half of the produce and nuts and 18 percent of the rice produced in the United States (California Department of Food and Agriculture, *California Agricultural Statistic Review 2011-12*, 2012). Because of the size of California's agricultural economy, losses due to flooding could have long-term and wide-scale impacts caused by interruptions in planning, growing, and harvesting cycles, as well as impacts on seed inventories.

3.5 Critical Facilities Are At Risk

A number of critical facilities—essential facilities, lifeline utilities, and transportation facilities—tribal lands, and Department of Defense (DoD) facilities are exposed to flooding in California. Critical facilities include essential facilities, high potential-loss facilities, and transportation facilities. Essential facilities are defined as care facilities (such as hospitals and medical clinics), emergency centers, fire stations, police stations, and schools. Lifeline facilities are defined as facilities for wastewater, potable water, oil, natural gas, electric power, and communications. High potential-loss facilities are defined as dams and hazardous material sites. Transportation facilities are defined as facilities for airports, railroads ports, ferries, public transportation, and highways. Major flooding could result in significant impacts to these facilities, resulting in temporary loss of service, isolation, or closure, as well as in hindering flood emergency management response. Also, flooded water and wastewater infrastructure affects more than just residents living within the floodplain. For example, if a catastrophic levee failure in the Delta occurred, water supply would be disrupted for 60 percent of California residents and up to 3 million acres of productive agricultural lands. Loss of critical facilities would have wide-ranging effects because hundreds of facilities are in the floodplain, as shown in Table 3-4 and Figure 3-8.

Table 3-4. Number of Critical Facilities Exposed within 500-Year Floodplains by California Hydrologic Region

Hydrologic Region	Essential Facilities	High Potential-Loss Facilities	Lifeline Utilities	Transportation Facilities	Total
Central Coast	230	32	33	624	919
Colorado River	113	15	22	221	371
North Coast	54	35	13	461	563
North Lahontan	3	9	2	75	89
Sacramento River	510	147	53	1,620	2,330
San Francisco Bay	466	303	58	1,022	1,849
San Joaquin River	298	134	29	901	1,362
South Coast	1,299	772	87	2,074	4,232
South Lahontan	77	10	8	94	189
Tulare Lake	254	71	25	808	1,158
TOTAL	3,304	1,528	330	7,900	13,062

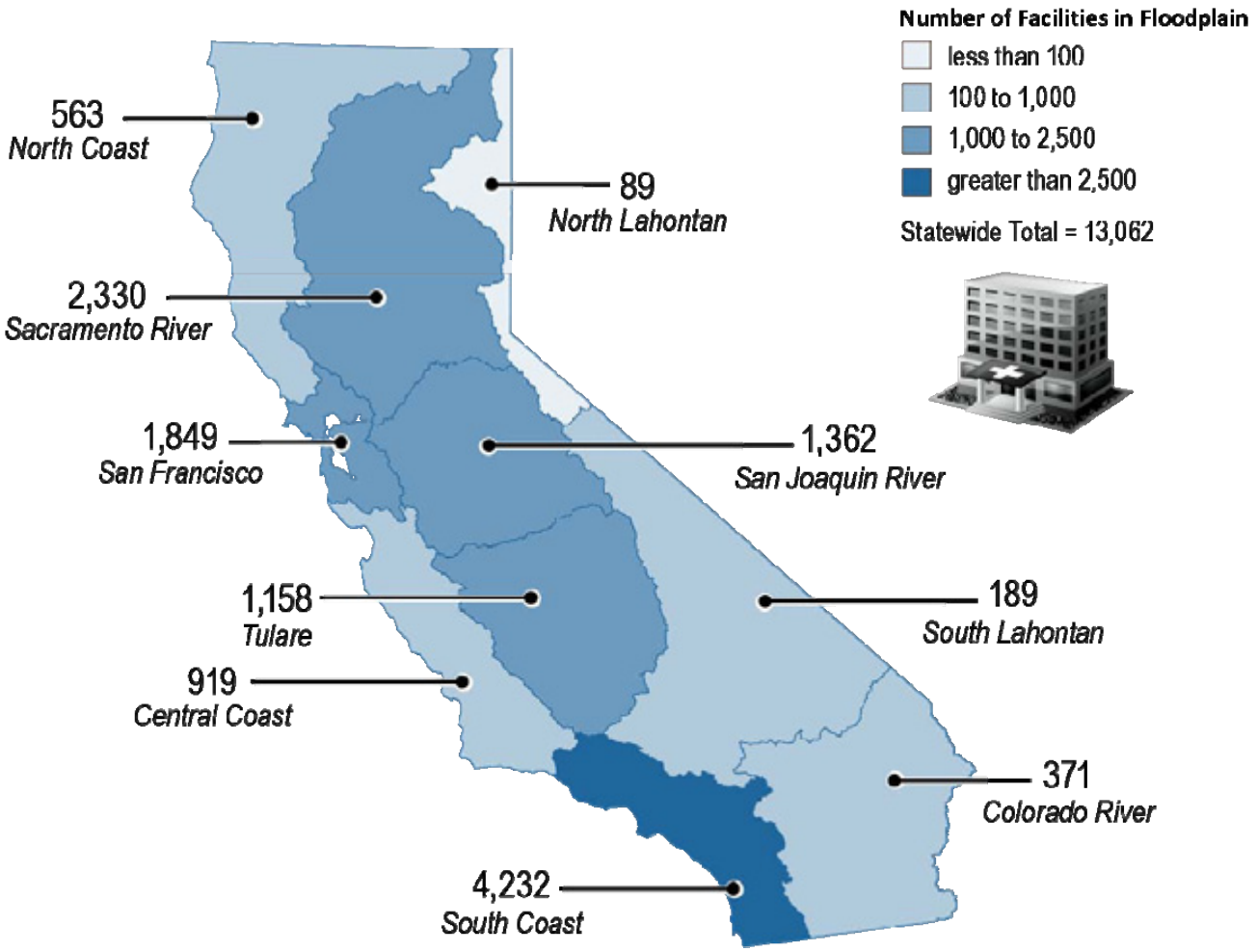


Figure 3-8. Critical Facilities within the 500-Year Floodplains by Hydrologic Region

Specifically, flooding can have the following impacts:

- The Sacramento River, San Francisco Bay, and South Coast hydrologic regions have the most essential, high potential-loss, and lifeline facilities exposed within both the 100-year and 500-year floodplains. Although the total numbers are relatively similar for the 100-year floodplains, the South Coast Hydrologic Region has far more exposure of these types of facilities within the 500-year floodplains, with more than 40 percent of the state's exposed essential, high potential-loss, and lifeline facilities.
- Exposure of transportation facilities occurs in many parts of the state, with the Central Coast, Sacramento River, San Francisco Bay, San Joaquin River, South Coast, and Tulare Lake regions having many exposed transportation facilities within both the 100-year and 500-year floodplains.

- Native American tribal land areas are exposed to potential flooding in many parts of the state, as shown in Table 3-5. The majority of exposed Native American tribal lands are in the Colorado River and Sacramento River hydrologic regions.
- The South Coast Hydrologic Region has the most DoD facilities exposed within both the 100-year and 500-year floodplains, although DoD facilities are exposed to potential flooding in many parts of the state. Table 3-5 also shows the acreage of DoD facilities exposed within 500-year floodplains.

Table 3-5. Native American Tribal Land and DoD Facilities Exposed within 500-year Floodplains by Hydrologic Region

Hydrologic Region	Native American Tribal Land Areas Exposed (Acres)*	Department of Defense Facilities Exposed (Acres)*
Central Coast	0	15,332
Colorado River	57,499	16,963
North Coast	5,748	0
North Lahontan	14	56,674
Sacramento River	2,833	5,841
San Francisco Bay	0	2,914
San Joaquin River	3	831
South Coast	586	4,337
South Lahontan	10	9,377
Tulare Lake	109	25,396

Notes:
*Many DoD facilities and Native American tribal land areas have large geographic footprints that might overlap more than one analysis region. As a result, a single DoD facility or Native American tribal land area could be counted in more than one analysis region. Because of this, the reported statewide totals will be less than the sum of the individual analysis regions.

3.6 Environmental Stewardship Suffers from Competing Regulations and Processes

Effective floodplain management finds the appropriate balance between providing for public safety while reducing risk to sensitive ecosystems. Threatened, rare, listed, or endangered ("sensitive") plant and animal species are exposed to flood hazards throughout the state, with all regions having at least 100 sensitive species exposed to flooding. The Central Coast, North Coast, Sacramento River, and South Coast, hydrologic regions each have more than 200 sensitive plant species exposed within the 100-year and 500-year floodplains. The Sacramento River, San Joaquin River, and South Coast hydrologic regions have the highest levels of exposure for sensitive animal species, with more than 125 sensitive animal species within both the 100-year and 500-year floodplains of each region. Table 3-6 provides a summary by hydrologic region of the quantities of sensitive species, both plants and animals that are exposed to flooding hazards.

Table 3-6. State and Federal Sensitive Species Exposed to Flood Hazard by Hydrologic Region

Hydrologic Region	100-year Floodplains			500-year Floodplains		
	Plants	Animals	Total	Plants	Animals	Total
Central Coast	202	111	313	204	112	316
Colorado River	78	99	177	85	101	186
North Coast	203	117	320	203	117	320
North Lahontan	68	46	114	68	46	114
Sacramento River	203	142	345	205	142	347
San Francisco Bay	167	106	273	169	110	279
San Joaquin River	130	131	261	131	131	262
South Coast	210	136	346	210	137	347
South Lahontan	100	113	213	104	113	217
Tulare Lake	94	101	195	94	103	197

Exposure of sensitive animal species to flooding within the 100-year floodplains is distributed among California counties, with 16 counties each having more than 50 animal species exposed. Riverside and San Bernardino counties have the most exposure, each with more than 100 animal species within the 100-year floodplains. Exposure of sensitive animal species within the 500-year floodplains is similar to that of the 100-year floodplains. Figure 3-9 shows the quantities of sensitive species within the 500-year floodplains in each hydrologic region.

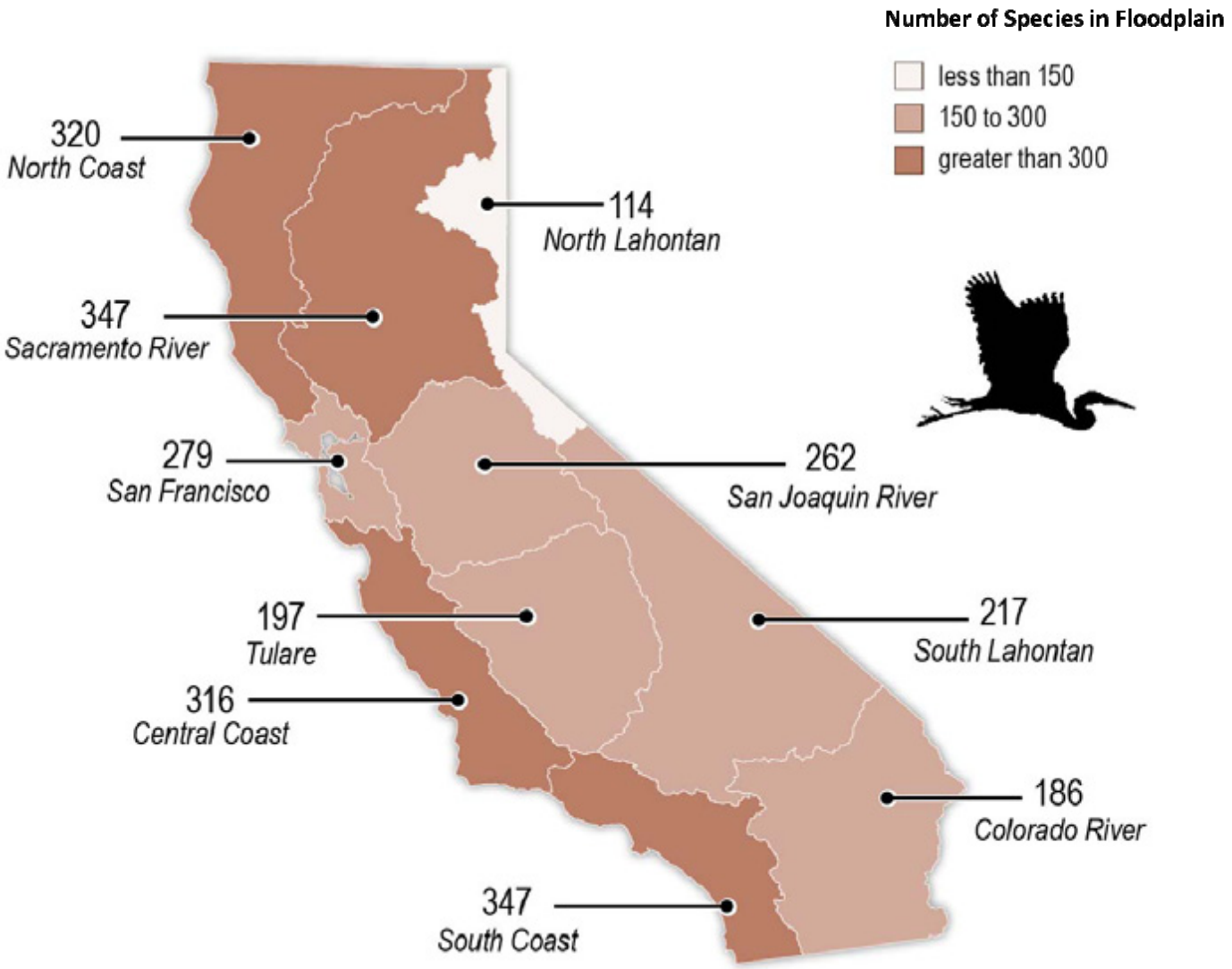


Figure 3-9. State and Federal Threatened, Endangered, Listed, and Rare ("Sensitive") Plant and Animal Species within the 500-Year Floodplains by Hydrologic Region

As the analysis of exposure demonstrates, sensitive-species habitat is commonly located in floodplains where flood management infrastructure development has occurred; this, along with other activities, can put the habitat at risk. Development in floodplains can permanently alter natural floodplain functions, destroy habitat of sensitive species, and reduce the beneficial connections between different types of habitat and adjacent floodway corridors. Floodplains also can provide a variety of regional and ecosystem benefits. Well functioning floodplains not only provide habitat for a significant variety of plant and wildlife species but also help by naturally reducing flood flows. Flooding of this habitat can have positive and negative impacts. Positive impacts from flooding include recharge of groundwater basins, improved water quality, and erosion control. Negative impacts of flooding include habitat degradation from deposits of debris, contaminants, and decay; as well as endangering species directly by removing habitats and inundating areas needed for refuge and retreat.

Protecting sensitive-species habitat and other broad environmental benefits of effective floodplain management suffer from competing regulations and processes. Local flood management agencies are often faced with competing regulations and processes when developing new or maintaining existing infrastructure. This issue exists for traditional structural approaches and for multiple-purpose projects that include natural floodplain functions. Many existing regulatory processes were developed to assess or protect against a single issue/concern and do not take into account the challenges associated with multiple-purpose projects that might address one issue while exacerbating another. Even projects that were developed to consider natural functions struggle to maintain floodplain capacity due to antiquated processes and conflicting resource agency standards.

3.7 Future Uncertainties Could Impact Flood Exposure

Flood exposure in California is dynamic because influencing factors are constantly changing. For example, exposure over time to flood hazards for a selected location within the state could increase or decrease as a consequence of factors. This section provides a qualitative discussion of flood exposure impacts that could result from future uncertainties, such as changes in population growth patterns, land use changes, and climate changes.

3.7.1 How Population and Land Use Changes Impact the Flood Hazard Exposure Analysis

Population growth patterns could alter the number of people, as well as the amount of property and infrastructure exposed to flood hazards. New development to accommodate population growth could occur within existing floodplains near creeks, streams, the coast, or other bodies of water, thus increasing exposure to flood hazards. For example, in portions of Marysville, Sacramento, Stockton, and Yuba City, new developments have been constructed in areas subject to flooding, where flood management measures were put in place (e.g., levees). Although flood management measures provide a certain level of risk reduction, new development in the floodplain exposes additional people and structural assets to potential flood hazards. This is important because California's population increased by about 10 percent, from almost 34 million to 38 million between 2000 and 2010.

Future conditions, including increases in population and changes in growth patterns, are likely to put to more people and property at risk of flooding hazards.

3.7.2 How Climate Change Impacts the Flood Hazard Exposure Analysis

Climate change could have a significant impact on the timing and magnitude of runoff in California. In addition, increasing temperatures could result in a rise in sea level, which likely would result in an increase in flood events. These changes could result in expansions of the 100-year and 500-year floodplains, thereby causing an increase in the people, property, and infrastructure exposed to flood hazards in the future. The potential future climate change effects on precipitation and runoff patterns and on the sea level rise, including the effects that these changes might have on exposure to flood hazards, are described in the following sections.

Changes in Precipitation and Runoff Patterns

Climate change is projected to cause global increases in temperatures that will likely lead to shifts in the timing and magnitude of precipitation and runoff in California. Researchers suggest that, although the total volume of precipitation is not likely to change significantly during the next several decades, the seasonal timing of the precipitation might shift, which could increase flood peak flows and flood volumes (Miller et al., 2003; Fissekis, 2008; CEC, 2009b; Das et al., 2011). Increased temperatures may alter precipitation and runoff patterns, resulting in higher snowline elevations, snowmelt occurring earlier in the year, and less overall snowpack. If precipitation events occur concurrently with warmer temperatures, more of the precipitation would fall as rain rather than snow.

Such changes would increase the extent and depth of floodplains because more watershed area contributes to direct runoff. In this case, the precipitation would flow into the watersheds instead of accumulating as snowpack, thus increasing the amount of runoff at that time of the year. This change would produce temporary shifts in reservoir inflows resulting in significant challenges for flood storage capacity in major reservoirs.

Increased temperature alone might be expected to alter flooding patterns; however, changes in storm types, frequencies, or magnitudes might result in more direct impacts. Historically, the most dangerous storms in California have been extreme events (e.g., warm and wet storms that strike in winter, producing intense rains over large areas).

Therefore, climate change likely will result in more frequent extreme precipitation events. Although uncertainties remain about future changes in long-term average precipitation rates in California, it is generally expected that extreme precipitation episodes will become even more extreme as the climate changes (Dettinger, 2011). The projected increases in the frequency and magnitude of extreme storm events would result in increased exposure of population, property, and facilities within the 100-year (1 percent) and 500-year (0.2 percent) floodplains in many parts of the state.

Sea Level Rise

The projected increases in future temperatures would result in sea level rise due to melting land-based glaciers, snowfields, and ice sheets, along with thermal expansion of the ocean as the surface layer warms (DWR, 2008). In the last century, sea level has risen about 20 centimeters (cm) (7 inches) along California's coast (DWR, 2008). Figure 3-10 shows the projected range in potential sea level rise in the future.

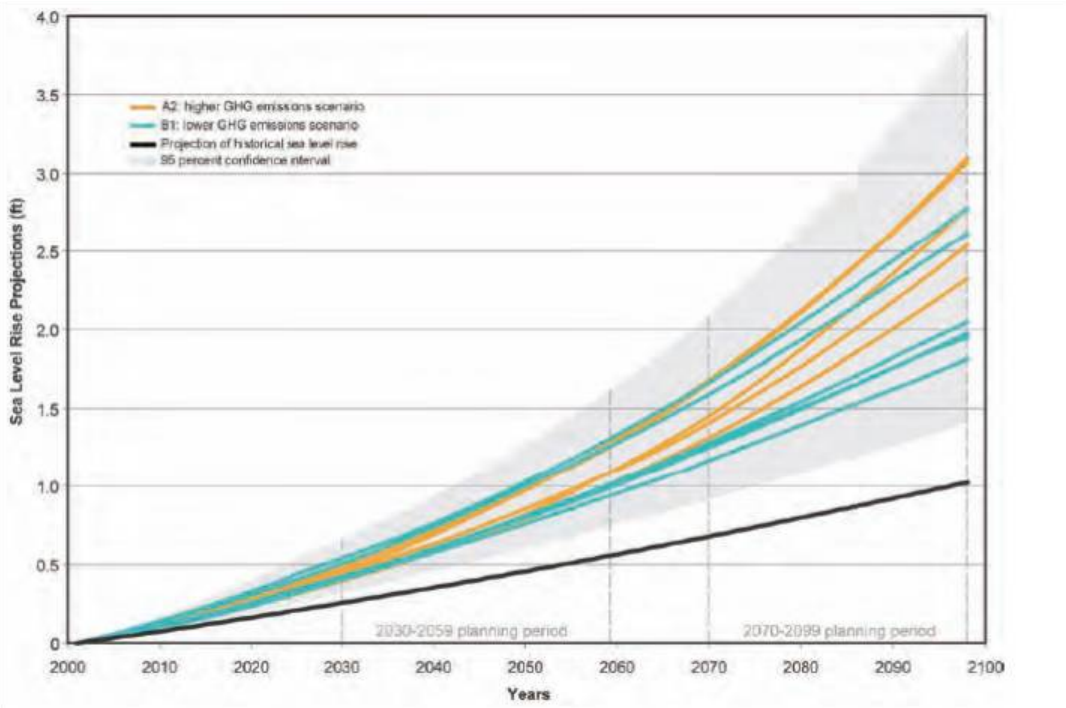


Figure 3-10. Sea Level Rise Projections Based on Air Temperatures from 12 Future Climate Scenarios
(CEC, 2009a)

Continuation or acceleration of this sea level rise, in combination with changes in precipitation and runoff patterns, likely would result in an increase in flood events, especially in the Central Valley (Knox, 1993; Florsheim and Dettinger, 2007). In coastal areas, a rise in sea level is likely to produce more frequent and potentially more damaging floods, increasing the exposure of people, property, and infrastructure to flood hazards, not only by exacerbating existing hazards but also by increasing the size of coastal floodplains (CEC, 2009a; CEC, 2009c; Heberger et al., 2011). As an example, Figure 3-11 shows the projected increase in flood inundation in the San Francisco Bay under one scenario of sea level rise. In Figure 3-11, Plot A shows areas inundated or vulnerable to inundation under 100-year high-water levels for present day (blue) and a 150-cm sea level rise (red). Plot B shows the same areas inundated with a 150-cm sea level rise as in Plot A, but colored according to type of land use (Knowles, 2010). (Note that the inundation shown in Figure 3-11 does not take into account existing flood infrastructure along the San Francisco Bay shoreline.) This shows that impacts could be significant, especially in the south Bay Area where there are high levels of urbanization.

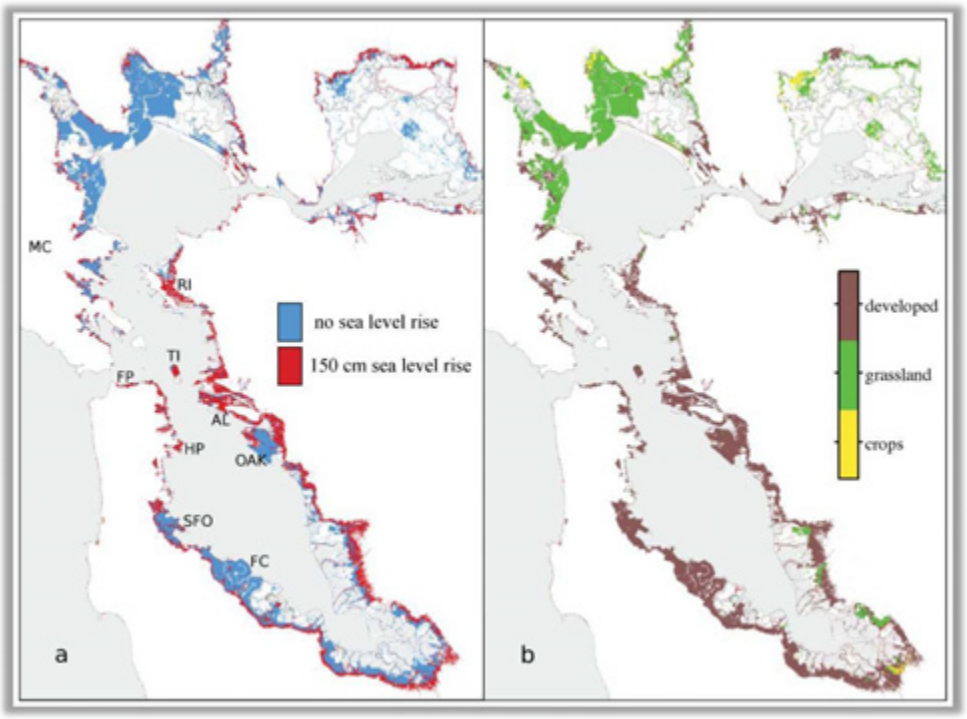


Figure 3-11. Projected San Francisco Bay Flood Inundation under a 150-cm Sea Level Rise Scenario
(CEC, 2009c)

3.8 Existing Flood Infrastructure Does Not Meet Current or Future Needs

California's flood management infrastructure has prevented billions of dollars of damage and saved many lives. However, resources for O&M and much-needed improvements have not kept up with demands, putting people and property at increased risk. Also, conditions, design standards, and environmental regulations have changed since the flood infrastructure was constructed. These changes have resulted in a complex project development and O&M process. Local agencies often have difficulty permitting O&M activities to maintain capacities in existing infrastructure, and some flood management infrastructure has been abandoned. For example, some levees built by developers have been abandoned, and unattended channels have clogged with vegetation and debris.

Oroville Dam

Today, California has more than 20,000 miles of levees and channels, more than 1,500 dams and reservoirs and a number of other flood management infrastructure. This information was compiled from thousands of different sources, including the California Levee Database (CLD), the Division of

Safety of Dams (DSOD) list of dams, FEMA, and information provided by local agencies. Figure 3-12 provides an overview of the locations and types of flood management infrastructure that exists statewide. Additional information on infrastructure is provided in *Attachment E: Existing Conditions of Flood Management in California (Information Gathering Findings),* and maps of available electronic infrastructure data can be found in *Attachment D: Summary of Exposure and Infrastructure Inventory by County (Mapbook)*.

Even with the significant investment in infrastructure in California, flood exposure remains significant. Local, State, and Federal agencies continue to identify flood management solutions to address residual risk. As part of the SFMP information gathering effort, proposed flood management projects in different stages of planning and implementation were identified, as shown in Figure 3-13, including:

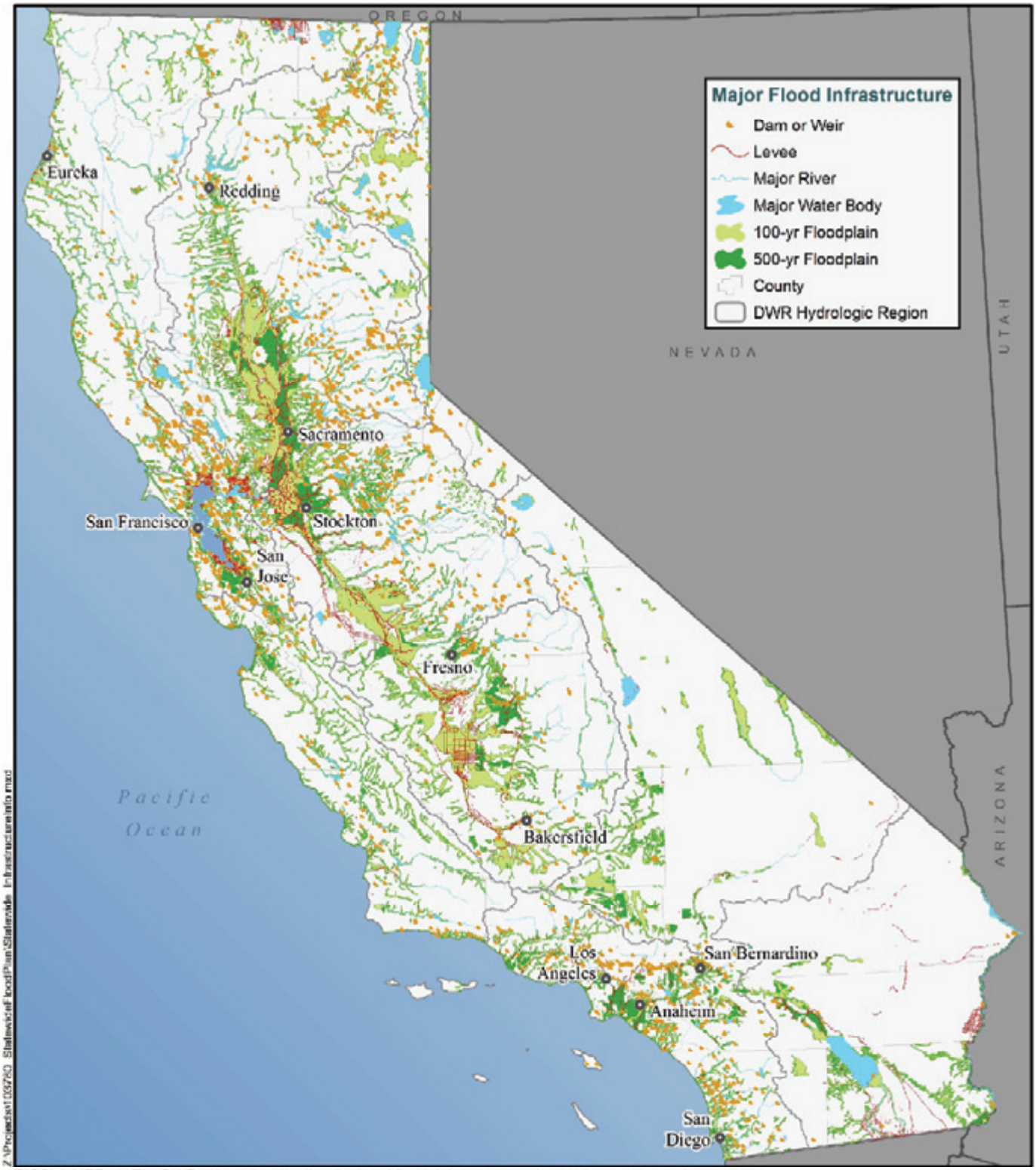
- More than 800 local projects statewide with costs totaling about $12 billion
- 62 USACE-partnered projects with costs totaling more than $6 billion
- Between $14 billion and $17 billion in potential improvements within the State Plan of Flood Control (SPFC)[3], as recommended by the Central Valley Flood Protection Plan (CVFPP)
- Between $0.1 billion and $17 billion in potential flood risk reduction improvements in the Delta

These identified projects and improvements are summarized in Table 3-7. Many are high-priority "crisis projects," which are necessary to keep infrastructure functioning properly, and others are designed to improve risk reduction for residents and structures located in areas where there is flood risk.

Table 3-7. Summary of Ongoing and Potential Flood Projects

Project Types	Range of Identified Costs ($ billions)	Projected Risk Reduction within specified Floodplain
CVFPP Improvements	14 to 17	200-year for urban areas
Delta Improvements	0.1 to 17	Varies
Identified Local Projects	12	Uncertain
Identified USACE Projects	6	Uncertain
Total Cost of Identified Projects	$32 to $52	

[3] Proposition 1E (Disaster Preparedness and Flood Prevention Act of 2006). *The "State Plan of Flood Control" means the State and Federal flood control works, lands, programs, plans, conditions, and mode of maintenance and operations of the Sacramento River Flood Control Project described in Section 8350, and of flood control projects in the Sacramento River and San Joaquin River watersheds authorized pursuant to Article 2 (commencing with Section 12648) of Chapter 2 of Part 6 of Division 6 for which the board or the Department of Water Resources has provided the assurances of non*federal *cooperation to the United States, and those facilities identified in Section 8361.*



DISCLAIMER: *1) The DWR did not develop the displayed floodplain extents and cannot guarantee their accuracy.*
2) Due to scale of map, not all types of infrastructure are shown. For additional detail, see regional and county maps.

Figure 3-12. Major Flood Infrastructure

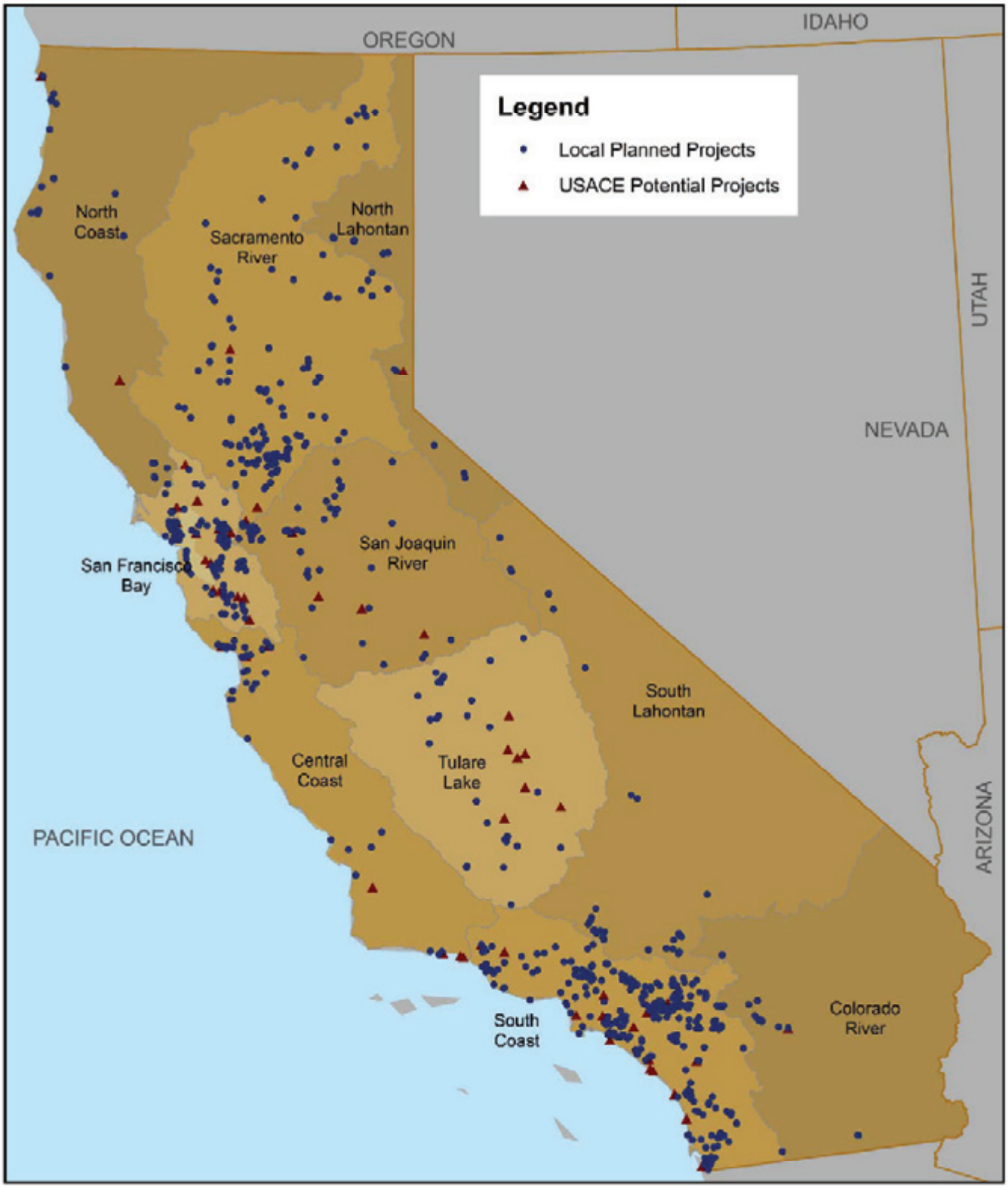


Figure 3-13. Summary of Ongoing and Potential Local Projects by Hydrologic Region

IWM Project along Guadalupe River

The improvements identified by the CVFPP are expected to provide risk reduction within the 200-year floodplains for urban areas within the SPFC area. However, the cost of providing risk reduction within even the 100-year floodplains in the remainder of the state is likely to be substantially higher than the costs shown because about 20 percent of the identified local and USACE project cost estimates have not been developed.

Even if all of these projects are completed, many regions in California will continue to be at high risk to flooding. Orange County estimates that it would take 90 years at current funding levels for the county to fund the approximately $1.5 billion in projects necessary to bring its facilities to a 100-year (1 percent) flood recurrence probability design level. Other major urban areas are facing similar situations. As infrastructure ages, proper maintenance on facilities falls behind due to funding and permitting costs, and project costs increase due to environmental requirements and increased competition for available funding sources. Many regions must complete flood risk assessments to identify additional projects to improve public safety. The projects included in this list are the projects that agencies perceive as feasible, but these are not necessarily all that are required to provide risk reduction within the 100-year floodplains.

3.9 Flood Management in California is Fragmented

In California, more than 1,300 local agencies have responsibility for flood management, as seen in Figure 3-14. Flood management is affected by a complex framework of public agencies with overlapping and, in some cases, conflicting mandates. Local flood agency governance structures are defined by enabling legislation, charter, ownership, or agreements with other agencies. Agencies contacted during the SFMP information gathering effort have varying duties and responsibilities, depending on jurisdiction size, location, geography, and governance.

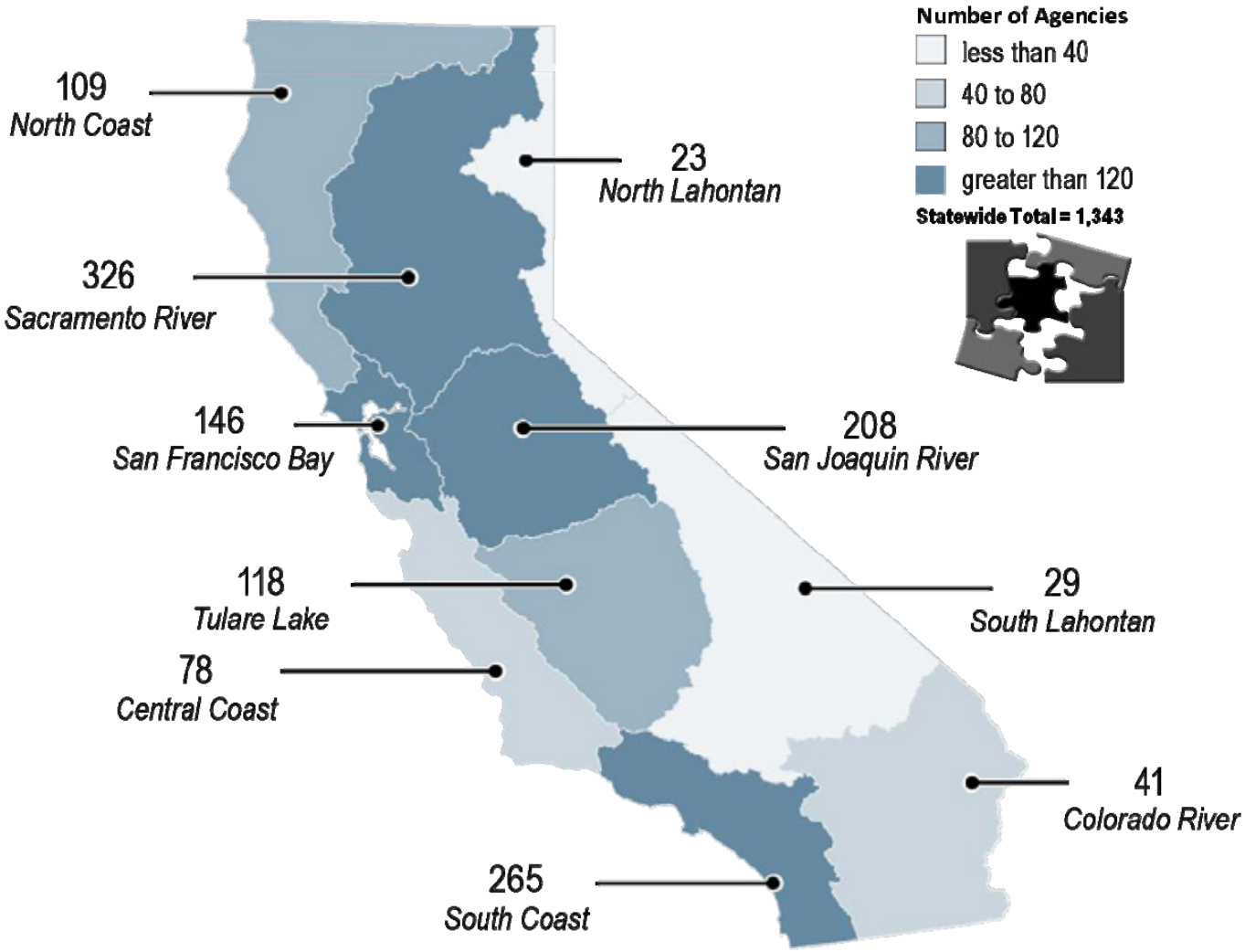


Figure 3-14. Number of Agencies with Flood Management Responsibilities by Hydrologic Region

Table 3-8 defines the seven most common types of agencies responsible for flood management. Responsibilities of local agencies vary with location and infrastructure ownership. The responsibilities of flood management agencies typically include watershed management and stormwater management, management of capital improvement plans (CIPs), flood safety, dam operations and safety, O&M of infrastructure, water supply, and protection of water resources. Responsibilities also can include coordinating with FEMA's NFIP, involvement in FEMA's Community Rating System (CRS) program, and assistance with flood emergency response.

Table 3-8. Primary Agencies with Flood Management Responsibilities

Agency Type	Responsibilities
Cities	Cities have the ability to incur indebtedness "for any or all, or any part of, the following purposes: (a) To protect the city from overflow by water. (b) To drain the city. (c) To secure an outlet for overflow water and drainage" (California Water Code, Division 5, Part 1, Chapter 1, subsection 8010).
Counties	Under the Government Code, counties have general authority to engage in flood control activities. In addition, Section 8100 of the Water Code states: Under such limitations and restrictions as are prescribed by law, and in addition to jurisdiction and powers otherwise conferred, the boards of supervisors, in their respective counties, may appropriate and expend money from the general fund of the county for any of the following purposes in connection with streams or rivers in the county: (a) The construction of works, improvements, levees or check dams to prevent overflow and flooding. (b) The protection and reforestation of watersheds. (c) The conservation of the flood waters. (d) The making of all surveys, maps and plats necessary to carry out any work, construction or improvement authorized by this article. (e) The carrying out of any work, construction or improvement authorized by this article outside the county if the rivers or streams affected flow in or through more than one county. (California Water Code, Division 5, Part 1, Chapter 2, subsection 8100)
Tribal Entities	Tribal entities are defined as Federally recognized tribes and tribal communities. The difference between Federally recognized tribes and other tribal communities is that the Federally recognized tribal entities are eligible for funding and services from the Bureau of Indian Affairs. Some of the tribal entities are responsible for construction, maintenance and operations and stormwater systems.
Special Districts	Special districts are government agencies set up by local residents of an area to provide a specific service. Some of these districts, such as flood control districts, are formed for the sole purpose of controlling flood and stormwater to protect life and property. Other districts, such as flood control and water conservation districts, not only manage flood and stormwater to protect life and property but also are responsible for the beneficial use of the water, including replenishing the groundwater. Also, special districts may be water agencies that are responsible for managing and conserving water for domestic, industrial, agricultural, or hydroelectric energy.
Flood Control Districts	Counties can establish flood control districts to: (a) To protect and preserve the banks of rivers and streams and lands lying contiguous thereto from injury by overflow or washing. (b) To provide for the improvement of rivers and streams. (c) To prevent the obstruction of rivers and streams. (d) To assess, levy and collect within each district a tax for the district (California Water Code, Division 5 Part 1, Chapter 2, subsection 8110). In addition to flood control districts, a number of districts have dual responsibility. For example, Flood Control and Resource Management districts are responsible for managing water and other natural resources within the county.
Levee Districts	A levee district is a type of special district formed for the protection of the lands of the district from overflow and for the purpose of conserving or adding water to the sloughs and drains in the district (California Water Code, Division 19, subsection 70030). Levee districts are primarily responsible for construction and maintenance of drains, canals, levees, and other structural devices.
Reclamation Districts	Reclamation districts are another type of special district that commonly has flood management responsibilities. Reclamation districts were formed "for the reclamation of any land within any city, which land is subject in any manner, to overflow or incursions from the tide or inland waters of the State" (California Water Code, Division 15, subsection 50110). Reclamation districts are commonly associated with local agency flood protection efforts, especially in the Sacramento Valley and San Joaquin Valley. In California's Central Valley, reclamation districts were formed as early as 1868 to reclaim land inundated with water and to use the land for agricultural purposes.

The large number and complexity of flood management entities and their different responsibilities result in a number of challenges for planning, funding, permitting, constructing, operating, and maintaining flood management infrastructure. Typically, large urban areas have flood management agencies, and rural counties or those with low exposure to flooding are handled by emergency responders or a single contact at the county level.

Agency roles and responsibilities are both defined and sometimes limited by how the agency was formed—enabling legislation, charter, memorandum of understanding with other agencies, or ownership. This is notable because agency funding is tied to governance structure. Details regarding the relationship between funding and governance structure are provided in *Attachment I: Finance Strategies*.

Duties of flood management agencies sometimes overlap or must be coordinated with other functions. Examples of this include:

- Flood management agencies could be responsible for either managing or coordinating with surface water supply or groundwater management programs.
- Some agencies must coordinate with clean water programs under the jurisdiction of the National Pollutant Discharge Elimination System.
- Flood management is also part of land use planning and must be coordinated with emergency services.

White Pelicans on the Salton Sea

Other challenges that agencies face when implementing a project include:

- Agencies must navigate through a maze of new or conflicting regulations as projects are planned, constructed, operated, and maintained.
- Traditional planning processes rely on project proponents that typically have a narrow mission and a specific geographic focus. Such projects miss the opportunity to provide a broader suite of benefits that consider systemwide and regional benefits.

Complicated flood management duties are exemplified in Fresno County, where the agency responsible for flood management depends on the location and issue. Flood management responsibilities throughout Fresno County are shared among Fresno County, Fresno Irrigation District, Fresno Metropolitan Flood Control District, and Kings River Conservation District, in addition to many other smaller agencies.

Another example of complicated flood management responsibilities is in Imperial County. Although the Imperial County Planning and Development Services is listed as a participant in the IRWM program, all drainage in the county goes to the Salton Sea through Imperial Irrigation District (IID) drainage canals. Imperial County indicated that a dedicated flood management agency is needed to truly deal with flood management on a regional level, especially as development increases.

Overlapping and sometimes conflicting responsibilities and priorities among the many local, State, and Federal regulatory agencies further complicate the task of reducing risk to human life, property, economic interests, and the environment. These agency conflicts increase the difficulty of statewide coordination, funding, and development of comprehensive regional solutions to flood management. As an example, an agency focused on protecting fisheries might advocate habitat enhancement through gravel augmentation; on the other hand, the California Regional Water Quality Control Board might oppose such action. For local agencies with O&M responsibilities, the overall regulatory environment can significantly increase costs just to maintain existing public safety infrastructure to a minimum standard.

In response to widespread acknowledgement of the complexity generated by multiple agency roles, a number of forums have been established to facilitate more efficient management practices. For example, DWR supports a number of interagency regional planning efforts, and USACE participates in several integrated interagency efforts for managing dredge materials and levee maintenance. By using IWM strategies where interagency coordination and watershed-based planning are emphasized, multiple agencies can help foster informed decisions for flood risk reduction.

Expected annual damage is the value that measures the severity of flood loss in any given year. EAD does not mean that this amount of the damage will occur in any particular year, but rather that over a long period, the average damages will tend to approach that amount.

3.10 Most California Regions Lack Adequate Flood Risk Information

3.10.1 Inconsistent Risk Assessment Methods

Although California has a long history of flooding, flood risks have not been fully defined and do not have a common criteria or methodologies have not been established statewide. This is a result of different agencies defining flood risk using different approaches. FEMA, CalEMA, and many local agencies assess flood risk in terms of FIRMs, as well as the 100-year annual probability (1 percent) and 500-year annual probability (0.2 percent) flood events. However, DWR and the USACE assess flood risk as described in terms of expected annual damage (EAD). Table 3-9 provides a comparison of the FEMA and USACE approaches to assessing risk.

Table 3-9. Comparison of FEMA and USACE Risk Assessment Approaches

Component	FEMA Approach	USACE Approach
Purpose of Analysis	To develop a Flood Insurance Study that creates flood hazard maps to outline a community's different flood hazard areas.	The USACE and other water resources agencies utilize the system of accounts to do a comprehensive evaluation of flood management plans. The system of accounts includes National Economic Development (NED); Regional Economic Development; Environmental Quality; and Other Social Effects to better evaluate plans beyond purely economic measures. The NED account is a significant factor used in development and prioritization of the President's Flood Risk Management budget. The accounts are part of Principles and Guidelines.
Subject of Analysis	The area impacted by the 1 percent annual chance exceedance (100-year) and 0.2 percent annual chance exceedance (500-year) flood events, both of which are identified on FIRMs.	A detailed risk analysis assesses economic, life-safety, environmental, and social benefits of proposed flood risk management measures. In addition, it evaluates the consequences of a full range of possible flood hazards, considering the likelihood of the flooding, the performance of existing or proposed actions and measures, current and future exposure of people and property to flooding, and the vulnerability of both.
Methodology	Uses statistical analysis of river flow, storm tides, hydrologic/hydraulic analyses, and surveys of rainfall and topography to estimate likelihood of flooding. FEMA creates flood hazard maps that outline areas subject to this flooding. FIRMs do not describe consequences or consider uncertainty; FIRMs focus on hazard and performance (to a limited degree).	Computes consequence (economic and life-safety) considering the probability of floods of various magnitudes occurring, performance of levees and other flood risk management infrastructure, exposure and vulnerability of property and people to the hazard. The computations consider explicitly the uncertainty about information on frequency, exposure, performance, vulnerability, and consequences.
References	FEMA, *Guidelines and Specifications for Flood Hazard Mapping Partners*, April 2003 FEMA, *Document Controls Manual*, September 2006 FEMA, *Floodplain Modeling Manual: HEC-RAS Procedures for HEC-2 Modelers*, April 2002 FEMA, *Final Draft Guidelines for Coastal Flood Hazard Analysis and Mapping for the Pacific Coast of the United States*, January 2005	USACE, ER 1105-2-100, *Planning Guidance Notebook*, April 22, 2000 USACE, EM 1110-2-1619, *Risk-Based Analysis for Flood Damage Reduction Studies*, August 1, 1996 USACE, ER 1105-2-101, *Risk Analysis for Flood Damage Reduction Studies*, January 3, 2006

3.10.2 Data are not Available to Characterize Risk across the State

Only a small number of flood risk documents are available statewide. Approximately 700 of the more than 3,000 documents collected during the information gathering effort were initially identified as potentially containing at least one component of risk (e.g., loading, performance, exposure, vulnerability, and consequence). Further review of the documents revealed that only a few agencies had specific risk information on consequences and likelihood. This exercise also revealed that the majority of the agencies referred to FIRMs and Hazard Mitigation Plans (HMPs) as containing the only risk information available for the agency. HMPs identify potential hazards within a jurisdiction, primarily using FIRM and NFIP damage claims, which do not constitute a full risk assessment as defined by USACE.

Typically, local agencies do not perform a damage assessment or benefit-to-cost (B/C) analysis unless the project is seeking involvement and funding from the USACE or DWR.

The information gathering effort also identified that local agencies in 29 counties have worked with the USACE recently to develop a number of documents, including risk assessments, as shown in Figure 3-15. These studies were primarily completed in areas identified by local agencies where significant deficiencies in flood risk reduction existed due to under-designed infrastructure or lack of flood infrastructure. USACE risk assessments have been completed for major streams (e.g., Sacramento and Los Angeles rivers), high-risk population areas (e.g., Los Angeles area), and areas with recurring flood events (e.g., Napa and Santa Clara counties).

Most local agencies are not focused on calculating risk using the USACE method but have requirements that are based on reducing risk from the 100-year (1 percent) floodplain for compliance with FEMA's NFIP. Local agencies typically perform individual site-specific hydrologic and hydraulic studies to identify system deficiencies. For some studies, floodplains might be identified, but typically agencies do not have the topographic mapping needed.

In California, large areas exist where flood risk is not fully understood, as described in *Attachment G: Risk Information Inventory*. Figure 3-15 shows the locations where USACE studies have been completed. Another factor of note is that risk is not fully understood by many local agencies. A clear, consistent method to assess risk should be identified and implemented to help local agencies better understand and compute risk. This method could help set priorities for assessing risk across the state. Also needed are programs to increase public awareness about flood risk and flood management. The Flood Risk Notification Program is part of the DWR FloodSAFE California Initiative. The program's key goal is to increase flood risk awareness by effectively communicating that risk to individual property owners and the public, as well as to local, State, and Federal agencies. As of September 2010, DWR provides an annual written notice of flood risks to each landowner whose property is protected by SPFC levees and is within a Levee Flood Protection Zone.

Figure 3-15. USACE Risk Studies

3.11 Flood Risk is Not Adequately Understood

3.11.1 Common Misunderstanding of Residual Risk and Level of Risk Reduction

The limited amount of flood risk assessments and data available statewide made compiling a flood risk inventory difficult; however, research for the Flood Future Report provided flood hazard exposure information statewide. This information can help inform the public and policymakers about flooding hazards.

Property owners and residents are generally unaware of the potential damages from flooding because these events often have infrequent occurrences. Also, there is a misconception by the general public that a 100-year flood occurs only once in 100 years, when in fact it is a flood that has a 1 percent chance of exceedance in any given year. Such an event is only an estimated average based on records; however, a 100-year flood could happen multiple times in a given year. The public and policymakers also may believe that developing infrastructure to provide risk reduction within the 100-year floodplains will protect them from any storm. This inadequate understanding of residual risk can lead to land use decisions that put lives and property at risk by allowing development in the floodplain.

3.11.2 Land Use Decisions Can Put People and Property at Risk

Development in floodplains increases the number of lives and property assets at risk. The public and policymakers often do not understand that flood infrastructure only reduces flood risk but cannot eliminate the risk. In fact, infrastructure often reduces flood risk enough for an area to comply with the requirements for flood insurance, making urban development possible in areas where it once was not.

In addition, land use decisions might be made without regard to flood management issues or needs. In some agencies, improved planning could provide for flood management infrastructure needs (e.g., easements for channels or land set aside for detention) as part of development approvals, or planning could allow for expansion of existing infrastructure to meet upstream or downstream needs. Decisions for land use in a floodplain have widespread ramifications because flooding can have impacts on crucial needs, such as:

- Critical infrastructure, including interstate highways, airports, ports, transit facilities, gas and electric utilities, and military installations
- Vital services, such as hospitals, police and fire stations, schools and public infrastructure
- Water supplies and water quality, including treatment facilities, the State Water Project, and the Central Valley Project

3.12 Funding for Flood Management is Limited and Increasingly Unreliable

3.12.1 Existing Local, State, and Federal Funding

In California, flood management projects are generally funded through partnerships by one of the following groups:

- Local agencies or groups of local agencies
- Local agencies and the USACE
- State and local agencies
- Local, State, and Federal agencies

Typically, these funding combinations are determined for projects on a site-by-site, project-specific basis to take advantage of available funding sources. In many cases, this approach lacks a systemwide perspective and can result in a reduction of other water-related benefits. Also, this approach can induce unintended consequences, such as shifting of flood risks to other areas and/or creating negative impacts to the environment.

Figure 3-16 illustrates the average proportion of flood management expenditures by local, State, and Federal agencies between 2000 and 2010. Local agencies account for the largest portion of expenditures, averaging $2.04 billion per year, followed by Federal and State agencies at $470 and $330 million per year, respectively. Total expenditures for the decade between 2000 and 2010 were $2.84 billion. Expenditures vary over time, depending on factors such as State and Federal appropriations and bond measures.

San Joaquin River Flooding, 1997

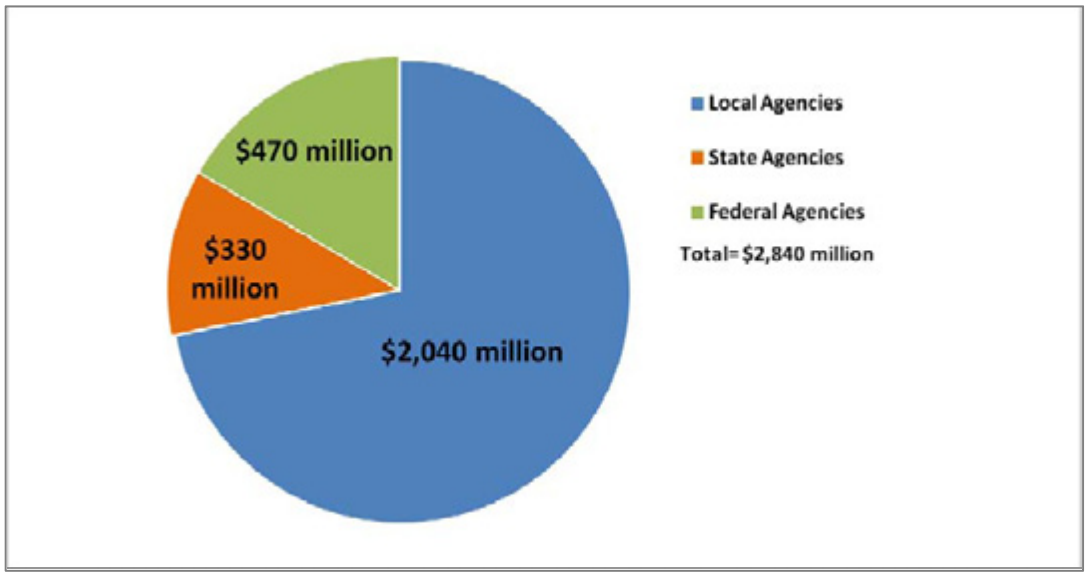


Figure 3-16. Average Annual Expenditures on Flood Management in California, 2000-2010

Source: SCO, 2013a, 2013b, 2013c, 2013d; Reclamation, 2012; FEMA, 2013

Between 2000 and 2010, annual project expenditures for flood management in California ranged from approximately $2.4 billion to $3.9 billion, as shown in Figure 3-17. Between 2000 and 2010, there were significant short-term infusions of funding for specific State projects. State fiscal year (FY) 2005/2006 includes $500 million in one-time funding from Assembly Bill (AB) 142, which appropriates funds for levee evaluation, repair, and related work, and for flood control system improvements. In California, flood management funding increased after 2007 when more than $5 billion in funding was authorized by the passage of Propositions 1E and 84.

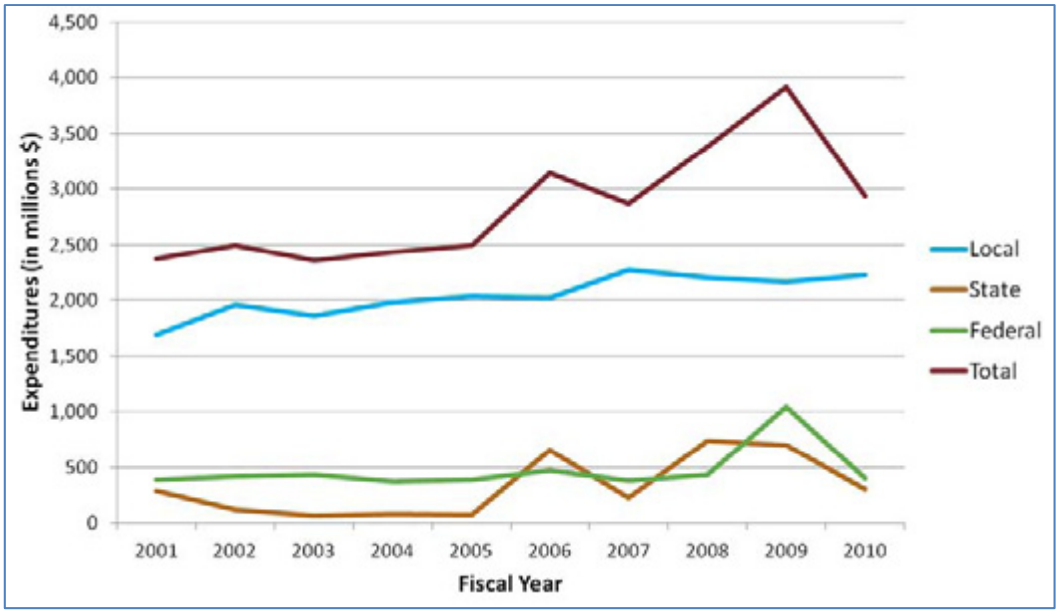


Figure 3-17. Total Annual Expenditures on Flood Management in California, 2000-2010

Source: SCO, 2013a, 2013b, 2013c, 2013d; Reclamation, 2012; FEMA, 2013

Figures 3-18 and 3-19 illustrate annual flood management expenditures by local, State, and Federal agencies for capital and O&M, respectively. Total annual local agency expenditures statewide ranged from approximately $1.7 billion to almost $2.3 billion in 2008, but the funding has been slowly declining from that high point, as has the U.S. economy. This decrease in local flood management funding is a result of declining development fees, property taxes, and impact fees, as well as competition for agency general funds. Most of the funding for local agencies went to operating expenses, with little available for construction and rehabilitation of infrastructure.

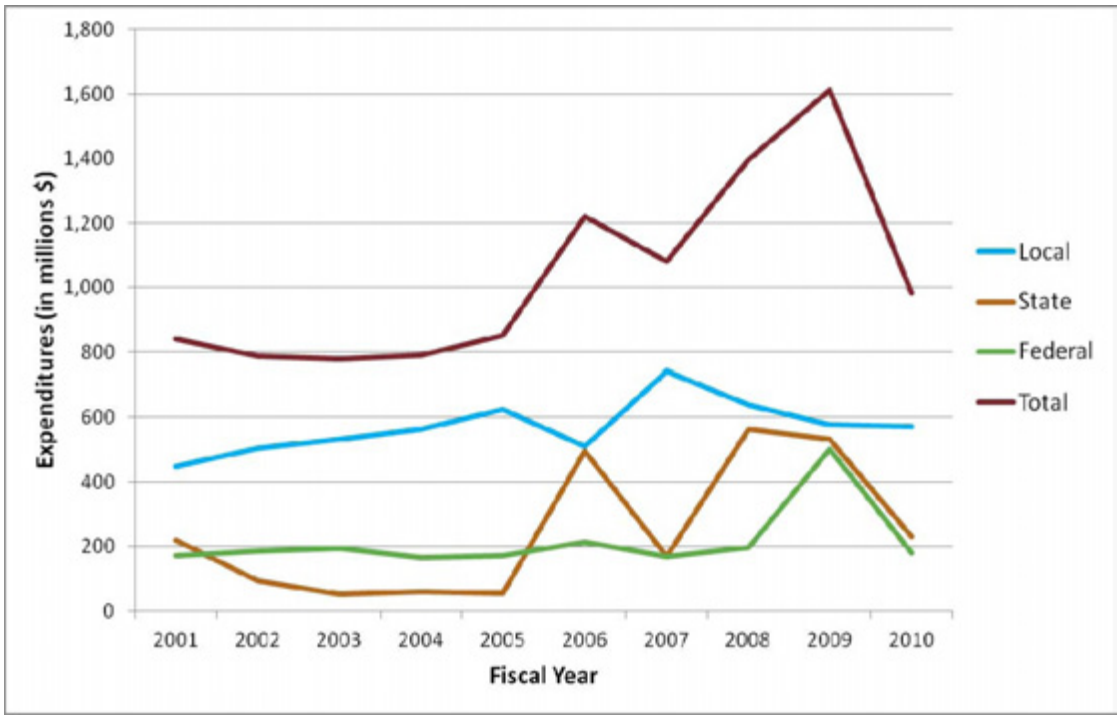


Figure 3-18. Total Annual Capital Expenditures on Flood Management by Entity in California, 2000-2010

Source: SCO, 2013a, 2013b, 2013c, 2013d; Reclamation, 2012; FEMA, 2013

Capital expenditures were approximately $11 billion for the 2000-2010 timeframe. These expenditures ranged from a low of almost $784 million in 2003 to a high of almost $1.64 in 2009. Also, capital expenditures for flood management projects during this period increased in the years after September 11, 2001, due to increased homeland security spending. In 2005, capital expenditures from the state increased due to the passage of Proposition 50 and due to an infusion of planning funding. Again in 2007, O&M expenditures increased as a result of Proposition 1E. Both capital expenditures and O&M were highest in 2008/2009 due to the infusion of Federal funding from the American Recovery and Reinvestment Act (ARRA) and from California bond monies, as shown in Figures 3-18 and 3-19.

O&M costs ranged from a low of $1.5 billion in 2001 to a high of over $2.27 billion in 2009. O&M accounts for the largest proportion of flood management expenditures in the state. Capital expenditures increased following Proposition 13, AB 142, and Propositions 1E and 84 in fiscal years 2002, 2006, and 2008, respectively. O&M expenditures follow similar general trends. Both capital and O&M expenditures

declined between 2009 and 2010 as ARRA and bond funded projects were completed.

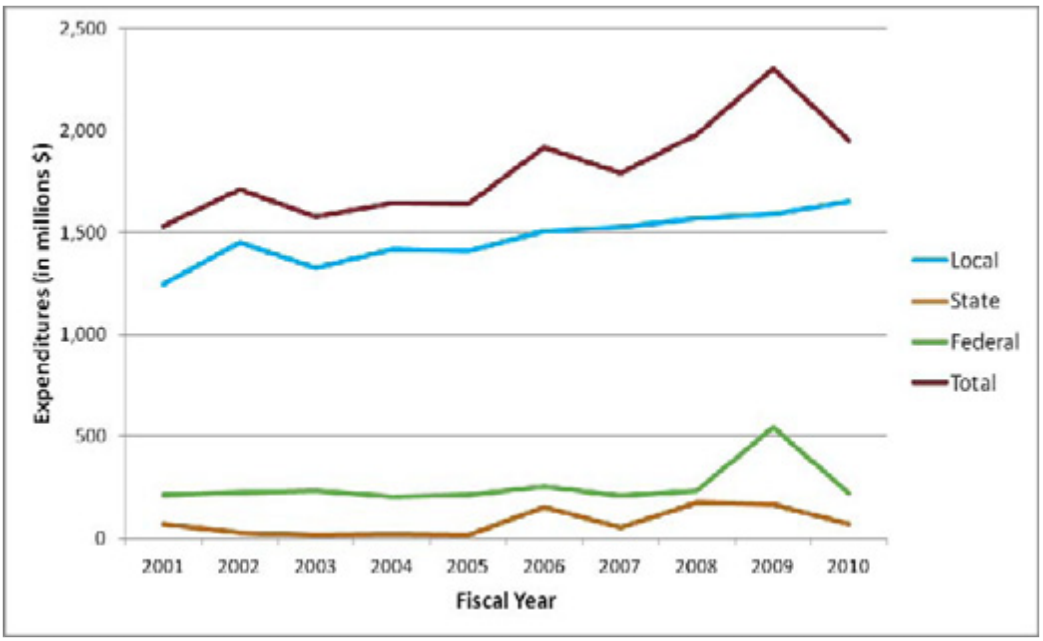


Figure 3-19. Total Annual O&M Expenditures on Flood Management by Entity in California, 2000-2010

Source: SCO, 2013a, 2013b, 2013c, 2013d; Reclamation, 2012; FEMA, 2013

3.12.2 Recent California Legislation and Bonds

Propositions

Key events, including the passage of Propositions 1E and 84, have influenced the recent availability of flood management funding in California. Important events have occurred, and pieces of legislation and bond funding have been issued to support flood management in California, including the following:

- **Proposition 204, the Bonds for Water Projects Act of 1996.** This proposition authorized $995 million in general obligation (GO) bonds for flood management and protection of the San Francisco Bay/Sacramento-San Joaquin River Delta (Bay Delta) Region.
- **Proposition 12, the Safe Neighborhood Parks, Clean Water, Clean Air and Coastal Protection Bond Act of 2000**. This proposition authorized the State to sell $2.1 billion in GO bonds for use in local assistance grants.
- **Proposition 13, the 2000 Water Bond**. This proposition authorized the State to sell $1.97 billion in GO bonds to support safe drinking water, water quality, flood management, and water reliability projects. The Flood Protection Corridor Program was established when California voters passed Proposition 13 (the "Safe Drinking Water, Clean Water, Watershed Protection, and Flood Protection Act") in March of 2000. This proposition provided funding for nonstructural flood management projects that include wildlife habitat enhancement and/or agricultural land preservation. Additional funding for these purposes was established under Proposition 84 and Proposition 1E.

- **Proposition 40, the California Clean Water, Clean Air, Safe Neighborhood Parks, and Coastal Protection Act of 2002.** This proposition authorized the State to sell $2.6 billion in GO bonds for conservation and protection of parks, coastline, and watersheds.
- **Proposition 50, the 2002 Bonds for Water Projects Act**. This proposition authorized the State to sell $3.4 billion in GO bonds. Proposition 50 included $825 million in funding for surface water storage, storage studies, water conveyance, levee improvements, supply reliability projects, ecosystem restoration, watershed programs, conservation, and water recycling. Part of the funding was earmarked for the agency known as the Collaboration among State and Federal Agencies to Improve California's Water Supply, or simply CALFED. CALFED was established in 1994, consisting of 12 State and 13 Federal agencies that focus on reliability and quality of water in the Delta. Historically, funding for CALFED has been a 60/40 percent split, with 60 percent coming from the State and 40 percent from Federal sources.
- **Proposition 1E, the Disaster Preparedness and Flood Protection Bond Act of 2006**. Proposition 1E originated as AB 140 and authorized the State to sell $4.09 billion in GO bonds for flood management plus additional funding for other water projects. Some key allocations of funds from Proposition 1E include $211 million to four levee improvement projects:
  - Sacramento Flood Control Agency Natomas Levee Improvement Program ($49 million)
  - Levee District No. 1 in Sutter County Lower Feather River Setback Levee at Star Bend ($16.3 million)
  - Reclamation District (RD) 2103 Wheatland Bear River North Levee Rehabilitation Project ($7.4 million)
  - Three Rivers Levee Improvement Authority Feather River Setback Levee ($138.5 million)
- **Proposition 84, the Safe Drinking Water Bond Act of 2006.** This proposition authorized $5.4 billion in GO bonds for natural resource projects, including $800 million for flood management and $65 million for water planning and design. Approximately $4.4 billion of Proposition 84 funds have been committed (State of California, 2010).
- **AB 142 (Nunez).** AB 142 provided an appropriation of $500 million from the General Fund for flood preparedness and repair of critical levees in May 2006. This followed an Executive Order by the governor declaring a State of Emergency based on USACE's findings of degradations within the California levee system.

Authorized funds
Those funds given the force of law by statute

Encumbered (committed) funds
Those funds that have been allocated for a specific purpose

Expended funds
Those funds that have already been spent

DWR Initiatives

State GO bonds have become an important source of water and flood management funding. In 1999 total water bonds were $3.8 billion, accounting for approximately 10 percent of total authorized State bonds. This increased to $22.9 billion by 2011 or 18 percent of total authorized bonds, largely due to Propositions 1E and 84. Current GO bonds will be fully allocated by the year 2018. Figure 3-20 illustrates the time series of outstanding GO bond funding for water-related activities, including flood management. Annual debt service for outstanding water bonds is approaching $80 per household because water bonds make up a larger proportion of flood and water funding. Total State annual debt service is $365 per household. Authorized GO bonds and Federal funding accounted for approximately two-thirds of total water management expenditures in FY 2012. State bonds have provided a significant source of water and flood management funding in California in recent years as Federal and local expenditures decreased.

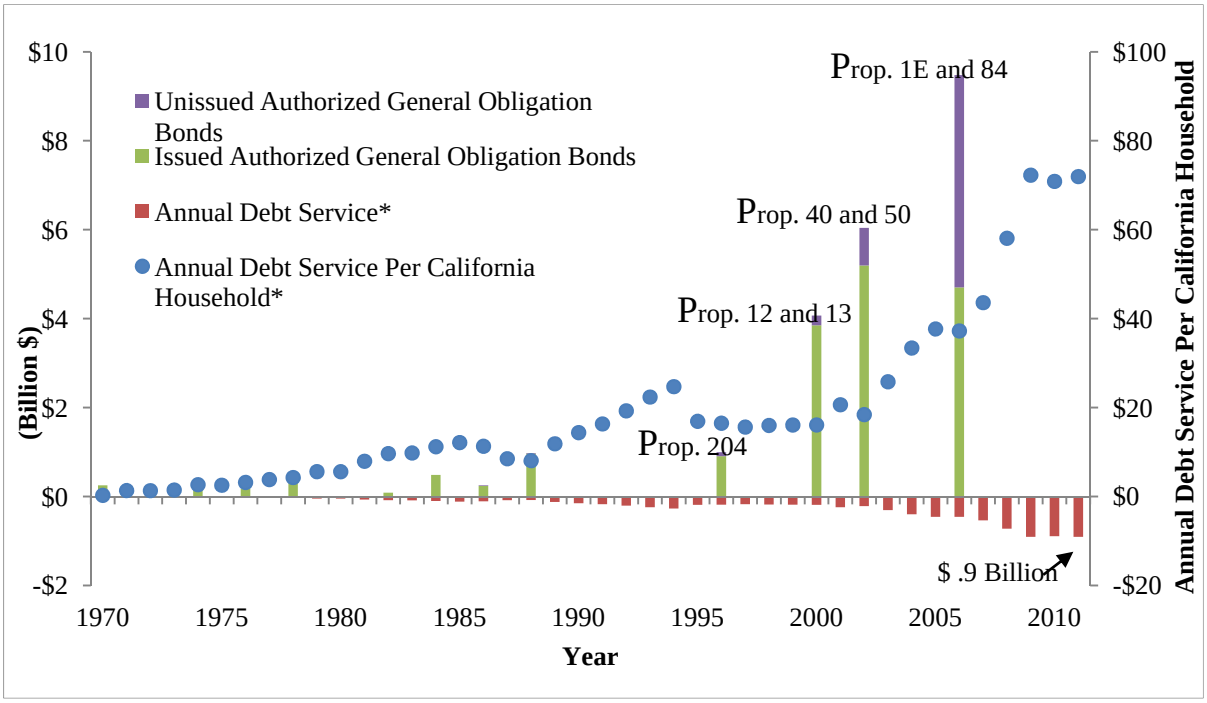


Figure 3-20. General Obligation Water Bond History, 1970-2010

** Figure note: Debt service is applicable to issued GO bonds only.*
Source: Data compiled from California Department of Finance.

3.12.3 Funding Demand

The demand for flood management funding depends on factors such as the cost of providing reduction of flood risk, the value of what is at risk, the likelihood of having a flood event, and the risk tolerance of those at risk. Across the state, little is known about most of these factors. Past statewide estimates focused on property value of what is exposed to flood hazard, but those efforts do not consider the broader economic impacts of flood-induced disruptions or the impacts associated with potential loss of life.

This section provides an estimate of the future demand for flood management funding. The minimum demand level is represented by the current flood

management projects in the planning or implementation stage. Information on the cost of projects being considered by entities across the state was compiled for analysis; these projects represent those that local agencies have identified in their short-term or long-term planning efforts. These projects, or levels of expenditure, do not represent a specific level of risk reduction for the probability of a specified flood event occurring in any given year (e.g., 100-year flood, 200-year flood, 500-year flood) statewide.

Local Projects from Information Gathering

More than 800 local projects, totaling approximately $12 billion in project costs, were identified throughout the state. However, this estimate is low because approximately 20 percent of the projects listed do not have cost estimates. In addition, the project list does not capture the full picture of flood infrastructure needs to meet increased potential flood exposure (i.e., new capital projects) or rehabilitation and replacement of aging infrastructure. This is the result of current regulatory and financial circumstances and the changing nature of flood risk over time. Table 3-10 provides a summary by hydrologic region of the number and total cost of identified planned projects. Detailed information for each project is in *Attachment E: Existing Conditions of Flood Management in CA (Information Gathering Findings.*

Table 3-10. Local Planned Projects by Hydrologic Region

Hydrologic Region	Total Local Planned Projects	IWM Projects	Projects with Cost	Projects without Cost	Total Cost ($ million)
Central Coast	42	29	25	17	280
Colorado River	24	1	21	3	70
North Coast	26	15	15	11	110
North Lahontan	13	5	4	9	20
Sacramento River	160	67	80	80	2,320
San Francisco Bay	118	43	101	17	1,970
San Joaquin River	55	25	47	8	730
South Coast	335	63	325	10	5,700
South Lahontan	33	21	29	4	170
Tulare Lake	30	18	27	3	240
TOTAL	836	287	674	162	11,610

Central Valley Flood Protection Plan Investments

As part of its State Systemwide Investment Approach (SSIA), the CVFPP has identified the State's preferred approach for modernizing the SPFC to address current challenges and affordably achieve the CVFPP goals of improving flood risk management, improving O&M, promoting ecosystem functions, improving institutional support, and promoting multibenefit projects. The SSIA provides guidance for future State participation in projects and programs with IWM approaches in the Central Valley.

The SSIA, as proposed in the CVFPP, consists of the following elements:

- Urban improvements that generally consist of the reconstruction, rehabilitation, or improvement of existing urban levees to achieve risk reduction within the 200-year (0.5 percent annual chance) floodplains.
- Rural-agricultural improvements that include levee improvements, hydraulic structure upgrades, and removal of rock revetment levees and other infrastructure that are no longer functional.
- Systemwide improvements that include physical actions or improvements with the potential to provide benefits across large portions of the flood management system and improve the overall function and performance of the SPFC in managing large floods.
- Residual risk management that includes enhanced flood emergency response, enhanced O&M, and agricultural conservation easements.
- Small Community Improvements that include improvements to small communities located behind the SPFC and non-urban levee evaluations.

Future needs of $14 to $17 billion have been identified in the CVFPP. These investments represent the proposed/planned improvements and do not represent remedies for the complete list of flood infrastructure needs. Table 3-11 presents a summary of these investments.

Table 3-11. CVFPP Investment Approach Cost Estimates by Element

Element	Low Estimate ($ million)	High Estimate ($ million)
Systemwide Improvements	5,150	6,500
Urban Improvements	5,500	6,670
Rural-Agricultural Improvements	1,080	1,190
Small Community Improvements	690	690
Residual Risk Management	1,520	1,870
Total	$13,940	$16,920

USACE Projects

For the 2012 Federal FY, 60 USACE proposed flood management projects were identified in California, with an aggregate total of approximately $6 billion. Of these 60 projects, 19 projects were funded for FY 2012 (see Table 3-12). These proposed projects consist of new and ongoing flood risk studies and authorized construction projects. These projects represent a snapshot in time from the USACE, which was developed as part of the information gathering effort for the SFMP. Funding for the identified projects is based on appropriations from Congress; therefore, actual project funding may not match this list for Federal FY 2012. The USACE recommends that funding appropriations be included in the President's budget. This request does not imply that any project will receive appropriations. Each funding request may or may not be included in the Energy and Water Appropriations for any given year. Projects from other programs, such as the Flood Plain Management Services and the Planning Assistance to States, are not captured here. A complete list of USACE flood projects, both planned and ongoing, is provided in *Attachment E: Existing Conditions of Flood Management in CA (Information Gathering*).

Table 3-12. USACE Planned Projects by Hydrologic Region

Hydrologic Region	Total Number of USACE Projects	Number of Projects Funded	Total Cost ($ Million)	Number of Projects Funded in FY 2012	Funding Appropriated In FY 2012 (millions $)
Central Coast	6	6	500	1	6
Colorado River	1	0	0	0	0
North Coast	2	1	150	0	0
North Lahontan	1	1	20	1	2
Sacramento River	3	3	230	1	10
San Francisco Bay	17	17	1,400	5	3
San Joaquin River	4	4	50	1	0.2
South Coast	19	18	2,700	7	41
South Lahontan	0	0	0	0	0
Tulare Lake	7	7	1,030	3	18
Total	60	57	$ 6,080	19	80

Delta Project Needs

There currently is no comprehensive flood risk reduction plan for the Delta, nor associated cost estimates. Costs for future levee improvements will depend on what level of risk reduction shown to be cost effective for individual islands/tracts and for the network of islands/tracts. Levees for individual islands/tracts not only provide a direct benefit to the areas they reduce risk, but also provide a benefit as part of the network of levees that define the water channels and the configuration of the Delta. As a result, the level of risk reduction provided by levees will vary.

Ongoing programs and investigation will influence future plans but will not produce a comprehensive flood risk reduction plan for the Delta. Therefore, past studies can be used to show a range of potential costs to improve Delta levees to achieve different levels of flood risk reduction. For a full explanation of what assumptions are used for the costs refer to *Attachment J: Recommendations to Improve Flood Management in California.*

High Water in the Delta, 1997

- **Hazard Mitigation Plan Geometry** – The HMP does not address seismic loadings. A rough estimate of not more than $100 million to improve all nonproject levees to HMP standards has been discussed by Delta levee engineers.
- **Delta-Specific PL 84-99** – Technical studies are not currently available to evaluate the cost of increasing most Delta levees to the Delta-specific PL 84-99 guidance; however, some initial estimates have been made:
  - The most recent available estimate was made by MBK Engineers for Delta Vision in 2008. The estimate to improve 635 miles of nonproject levees to the USACE Delta-specific PL 84-99 standard is $0.5 billion to $1.4 billion.
  - The CALFED Bay-Delta Program's Levee System Integrity Program Plan called for rehabilitation of 520 miles of Delta levees to Delta-specific PL 84-99 standard. The preliminary cost estimate (year 2000) to achieve this base level of risk reduction ranges from $0.6 to $1.3 billion.
- **Bulletin 192-82 Delta Levee Standard** – The plan included 27 major islands. The estimated costs for improvements (year 1982) were about $0.45 billion, which included environmental mitigation but did not address seismic loadings.
- **Delta Risk Management Strategy**
  - *Trial Scenario 1: Improved Levees* –Estimated costs for the improvements are about $10.5 billion.
  - *Trial Scenario 2: Armored Pathway* (Through-Delta Conveyance) – Estimated costs for the improvements are about $15.6 billion.
  - *Trial Scenario 3: Isolated Conveyance Facility* – Estimated costs for the improvements are about $14.8 billion.
  - *Trial Scenario 4: Dual Conveyance* – Estimated costs for the improvements are about $17.1 billion.

The above estimates show a wide range of potential improvements with estimated costs ranging from $0.1 billion to over $17 billion. With the lower estimate that accepts more levee failures, responsible agencies will need to place more effort on future recovery from flooded islands/tracts, or make decisions not to recover certain areas after flooding. Considering that these are the available extremes, the likely cost will fall somewhere between these estimates. More detailed site-specific technical studies are needed to select a cost-effective plan for flood risk reduction

and ecosystem restoration. Implementation of a comprehensive plan must be cost-shared and developed by stakeholders at all levels.

Estimated Cost of Known Projects

The total cost of specific projects identified to date ranges from more than $30 billion to $50 billion. The caveat with this total is that it represents only those projects currently in the planning cycle. This number does not necessarily represent the investments needed to meet a flood risk-reduction level that considers the damage that could occur due to exposed property or broader economic functions, or even to meet the probability of a specified flood event occurring in any given year (e.g., 100-year flood, 200-year flood, 500-year flood) statewide or an increased flood risk reduction level. The listed costs are restricted not only by what the agencies can realistically fund or finance but also by limits in appropriations at the State and Federal level.

The total cost of specific projects identified to date ranges from more than $32 billion to $52 billion, as shown in Table 3-13.

Table 3-13. Estimated Cost of Known Projects/Improvements

Projects	Cost ($ billion)
Local Projects	12
CVFPP Improvements	14 to 17
USACE Projects	6
Delta Improvements	0.1 to 17
Total	$32 to $52

Additional Costs Beyond Known Projects

Significant flood events have occurred every year in California since at least 1951. Although historical damage estimates for these events have not been compiled, estimates are available for some events, including the following:

- **March 1995 Central California.** A levee failed on the Pajaro River, causing agricultural crop damages, which were estimated at $67 million for the 3,280 acres that were flooded, and urban damages in the unincorporated town of Pajaro, which were estimated at $28 million. Two individuals drowned. The Salinas River inundated thousands of acres of farmland. The Carmel River washed out a bridge on State Highway 1 and combined with the Pajaro and Salinas Rivers to isolate the Monterey Peninsula. Stormwaters damaged Cambria. Santa Barbara streams, including San Antonio Creek and Sycamore Creek, damaged many homes and businesses and caused at least one death. Mudslides were common in the region.
- **1997 California Storms.** Between December 1996 and January 1997, a series of tropical storms hit northern California, spawning widespread flooding. In all, floods damaged more than 23,000 homes and businesses, and many thousands of acres of agriculture lands, as well as roads, bridges,

and flood management infrastructure. Damages were valued at approximately $2 billion (approximately $3.2 billion in 2012 dollars). More than 120,000 people were evacuated from their homes; nine people lost their lives; more than 300 square miles of land were affected.

- **June 2004 Lower Jones Tract Levee Failure.** The Lower Jones Tract levee failed, inundating the 5,894-acre island and causing approximately $90 million in damages.
- **January 2005 Southern California.** Five days of heavy rains caused widespread flooding throughout southern California, which incurred damages of $100 million. Twelve people died as a result of this event.
- **January 2006 Sonoma, Napa, and Corte Madera.** Flooding on Corte Madera Creek caused more than $70 million in damages in the Corte Madera area. Losses estimated at $135 million were due to flood damage by the Napa River in Napa County. Sonoma Creek damaged a mobile home park, bridge, and pipeline, and Nathanson Creek flooded 27 classrooms at Sonoma Valley High School.
- **March 2011 Crescent City Tsunami.** A tsunami generated off the coast of Japan, recorded throughout the California coast, struck Crescent City Harbor with an 8.1-foot wave, destroying much of the harbor and resulting in one death near Klamath. There was also major damage to docks and boats at Noyo Harbor. Estimated damage in the region was $24 million.

The demand for flood management funding includes costs for those projects that are currently in the planning process, as identified during the SFMP information gathering effort and in other studies. Funding demands also include the costs needed to achieve risk reduction against a specified flood event (e.g., 100-year flood event, 200-year flood event, or 500-year flood event), and those costs are not yet identified. The Flood Future Report presents a snapshot of the current flood management activities across the state. That snapshot reveals that many areas of the state have identified neither an appropriate level of flood risk reduction nor investments to achieve these levels. In addition, risk characterization has not been performed in enough detail to develop an estimate of the amount communities might be willing to spend to achieve a specified level of flood risk reduction.

San Dieguito River Flooding, 1980

Originally, one of the objectives of the information gathering effort was to compile a complete snapshot of the demand for funding statewide, but this information was not available. Although numerous locally planned projects exist, most of the projects contemplated were constrained by available funding and did not reflect the cost of meeting a given local or regional level of risk reduction against a specified storm event. The projects and improvements identified by the information gathering effort represent a total of between $32 and $50 billion, as shown in Table 3-13. Of the more than 800 local projects identified, 20 percent do not have any cost information.

In addition, these project cost estimates do not provide a consistent statewide risk reduction level. Instead, risk reduction levels range from below the 100-year level to as high as the 200-year level in some areas. As part of the information gathering effort, a few plans provided insight into the magnitude of the flood management funding needs. For example, the Orange County Flood Control District ($1.5 billion) and the CVFPP ($14 to $17 billion) plans are useful plans oriented at raising the level of risk reduction against a specific storm for a specific region.

The ultimate demand for flood management funding will be a function of the value of the property exposed to hazard, the likelihood of a flood event taking place, the estimated damages that would be caused by the event, the potential for loss of life, the estimated loss of broader economic functions ("ripple effects"), and a community's willingness to pay to avoid these impacts. In California, these factors can translate into significant economic impacts that can cause expanded impacts to the regions, California, and the U.S. For example, if flood damages disrupted the delivery of water for a significant amount of time, the economic impacts would be substantial and would reach far beyond California. Specifically, if water supply were disrupted in the Delta, impacts would affect not only agricultural production but also commercial businesses in the San Francisco Bay area and southern California.

Loss of function is a term used to describe the broader regional economic impacts (or ripple effects) caused by flood damages, such as the costs resulting from rerouting traffic and closing businesses, and from compromised services of water and wastewater treatment plants, and critical facilities such as hospitals. The population exposed to a 100-year event is 1.4 million people; five times as many people are exposed to the 500-year storm, with more than 7.2 million people. The value of residential and commercial properties exposed to flood hazard in the state was assessed at $146 billion for the 100- year flood event and at more than $580 billion for the 500-year flood event. These figures do not include public infrastructure such as water and wastewater treatment plants, airports, freeways, and other key facilities. The analysis of flood hazard exposure identified over 13,000 critical facilities that are located within the area affected by a 500-year flood event. Also, more than 137,700 acres of DoD facilities and 88,600 acres of Native American tribal lands are exposed to flooding from the 500-year storm event.

In the aftermath of Superstorm Sandy, Consolidated Edison Company of New York announced plans to spend $1 billion over the next 4 years to better protect equipment from major storms.

California has a significant risk of flooding, with millions of lives exposed and hundreds of billions of dollars in direct assets (structures, contents, agricultural assets, and critical public infrastructure) exposed. This exposure and the need to protect public safety, environment resources, and the State's economy are behind the demand for flood management funding in California. The Flood Future Report identified more than $50 billion in needs for specific projects and improvements that are now in the planning cycle. These projects (mostly site specific) collectively would not provide statewide risk reduction from the 100-year storm event. In fact, substantially more funding would be required to provide risk reduction from a basic storm, as shown in Figure 3-21. Additional engineering, economic, and risk

characterization studies are needed to develop accurate and detailed projections of the State's future funding needs.

This estimate seems reasonable based on the costs of Hurricane Katrina and other recent storms. Direct property damages from these storms were estimated at between $96 billion and $125 billion. The total economic loss from Hurricane Katrina has been estimated as high as $250 billion, taking into account the disruption of economic activity (*Swiss Re*, 2007). The economic impacts of Superstorm Sandy are not fully known, but local governments have estimated losses to be over $62 billion (AP, 2013). There are huge benefits statewide from flood management. Benefits include avoided disruptions to local and regional economies, support for continued economic development in numerous regions, and reduced losses for agricultural, commercial, and industrial production/income. Benefits also include improved public safety (life safety), as well as protection of environmental, recreational, and historical assets. Flood emergency management costs are sometimes left out of flood disaster calculations. These emergency management costs include funding for material, staff, and evacuations and can far exceed costs of flood infrastructure construction. These benefits, which help protect the nation's most populous state and the ninth largest economy in the world with a gross domestic product of nearly $2 trillion, drive the willingness to pay for improvements.

Figure 3-21. Demand for Flood Management Funding in California

If the $50 billion is assumed to represent current investments needed to provide risk reduction against a 100-year storm event, then total investment needed to reduce risk against the 500-year flood event could be assumed to be several times that amount. This is based on the 5.8 million increase in population exposed within the 500-year floodplains compared to 1.4 million in the 100-year floodplain; however, willingness to fund flood management for a 500-year storm event has not been demonstrated historically. For this reason, a conservative estimate for flood management investments based on what Californians would be willing to accept and pay for could be two times the $50 billion estimated for existing proposed projects. It can be conservatively estimated that over $100 billion is needed to reduce risk statewide.

3.12.4 Funding Challenges

Flood management agencies identified several finance and funding challenges as part of the information gathering effort. These issues are described briefly below; for more detailed descriptions, see *Attachment E: Existing Conditions of Flood Management in CA (Information Gathering Finding)*.

- **Flood Management agencies are often supported by local agency general funds and must compete with other public demands for resources.** Other public demands for funding include water supply, wastewater (sewer), transportation, parks, social services, education, and health services. Water supply and wastewater treatment funding is augmented by user fees. In addition, water supply and wastewater have exceptions to requirements of Proposition 218. For these reasons, flood management annual expenditures are much lower than water supply and wastewater expenditures, as shown in Figure 3-22.
- **Flood Management agencies have substantial restrictions to increasing property assessments due to Propositions 13 and 218**. The majority of flood management agencies depend on some type of property assessment as a revenue source; however, the ability to increase or initiate property assessments to satisfy revenue requirements has been restricted for some time in California. Agencies interviewed during the information gathering phase suggested that flood management and storm drainage agencies become exempt from the requirements of Proposition 218, or at least be treated similar to water and wastewater utilities.
- **Agencies that are partially funded through development fees or special projects assessments can be limited by assessment-zone boundaries.** These assessment-zone boundaries impose substantial limitations on the uses of funds. This is important because downstream flooding can be caused by upstream activities. Also, the solution or best management action for a flooding issue might be located outside of the assessment-zone boundary.

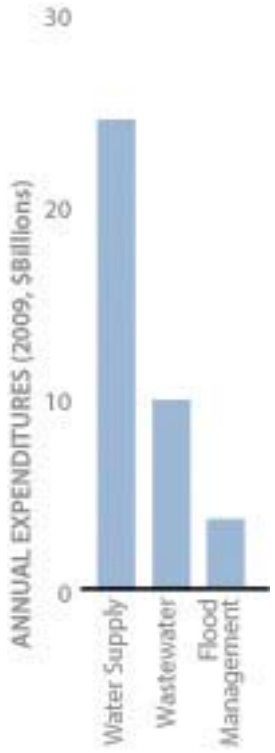


Figure 3-22. Funding Expenditures for Water Supply, Wastewater, and Flood Management

Water and the California Economy- Technical Appendix, Public Policy Institute of California, 2012

- **Funding for flood management projects is often dependent on infrequent flood events that temporarily raise public awareness.** Funding for flood management usually increases only following a flood disaster and then gradually decreases especially during economic downturns and dry water years.
- **Agencies that depend upon impact fees are affected by the slowdown in growth**. Although impact fees for storm drainage or flood management are a good option for growing communities, this source of revenue dries up when growth is stagnant. Agencies interviewed discussed the impacts of reduced development, along with the associated impacts on fees and the agency's funding ability.
- **Flood management budgets and project planning costs often do not adequately address full life-cycle O&M needs and environmental mitigation.** A significant amount of existing flood management infrastructure was constructed before the requirements for environmental mitigation were included as a component of project development. Many of these projects now face new permitting requirements with associated higher, unplanned costs. This has lead to benign neglect of some infrastructure and costly re-permitting for other projects. Also, many projects do not include the full life-cycle cost of O&M during project development. This funding deficit is affecting the ability of agencies to set aside replacement funds for deteriorating infrastructure.
- **Smaller agencies often do not have the resources to prepare funding applications.** Because some of the information requested on grant or loan applications is information not typically collected by the agency and not quickly developed, smaller agencies might not have the resources to prepare an effective application. Agency interviewees suggested that the State provide resources to help with applications.
- **Agencies have difficulty raising matching funds for Federal programs.** Many of the agencies are somewhat dependent on Federal or State funds for major capital improvements; however, with limited local revenue generation, many agencies cannot access some of the available Federal funds because they cannot raise the required matching funds. Agency interviewees stated that agencies were "leaving money on the table."
- **Agencies believe Federal funds are becoming scarcer.** With the fiscal issues the Federal government faces, most agencies believe that Federal funding programs will be reduced, if not eliminated. Reductions in Federal spending signal that USACE might not continue to fund studies or ongoing projects at the same rate as in the past.

3.13 Other High-Level Challenges Facing Flood Management

Some long-range issues exist for which both DWR and USACE are working to find solutions. Although they are outside the scope of the Flood Future Report, these issues should be acknowledged because they were identified as key concerns during the information gathering effort. The high-level challenges discussed below, along with a summary of the current status of the issues, include:

- Sacramento – San Joaquin River Delta
- Federal Disaster Relief Policies
- Federal Credit for Non-Federal In-kind Contributions
- Federal Budgeting Process
- NFIP Modernization

Upper Jones Tract Levee Break, June 2004

3.13.1 Sacramento-San Joaquin River Delta

The Sacramento-San Joaquin River Delta and Suisun Marsh are at the confluence of the Sacramento River and San Joaquin River basins, which drain about 40 percent of California. The Delta provides a major source of water supply to over 60 percent of California residents and is a vital source of water supply for agriculture. The Delta is a unique place defined by its ecological value as the transitional ecosystem from fresh to salt water and by its extensive levee system. The Delta consists of approximately 70 major islands and tracts encompassing about 700,000 acres located behind levees. Virtually all assets and attributes of the Delta are dependent

upon this levee system. Levees reduce flood risk to land areas near and below sea level and provide for a network of channels that direct movement of water across the Delta. The State of California has significant interest in the benefits provided by Delta levees, which have been legislated in the California Water Code (Section 12981, for example). The Suisun Marsh is a similar wetlands area immediately downstream from the Delta, encompassing an additional 50,000 acres.

The Delta is unique, not only as a levee system but also as an influence on existing DWR flood management programs. For more information on the Delta, refer to *Attachment J: Recommendations to Improve Flood Management in California* and the Bay/Delta Office of DWR at http://baydeltaoffice.water.ca.gov/.

The Delta is a prime example of why IWM is important in California. Due to its location, importance for much of California's water supply, deteriorating ecosystem conditions, questions about levee integrity and feasibility for improvements, and other issues, flood management cannot be considered in isolation of other resource needs. The importance of the Delta and its levees to the State has been included many times in legislation and codes. In addition, multiple Federal and State processes are underway to solve a variety of resource management problems in the Delta, and several include consideration of levee improvements or other flood management actions. These plans, especially the Bay Delta Conservation Plan (BDCP) and the Delta Stewardship Council (DSC) Delta Plan, are expected to alter Delta conditions and will influence the future of IWM in the Delta. Implementation of these programs would alter ecosystem conditions and water infrastructure, which would influence Delta flood risk; therefore, flood management in the Delta needs to be considered as part of these planning efforts.

High Water in the Sacramento-San Joaquin Delta, 1997

3.13.2 USACE Public Law 84-99 Relief Policies

USACE administers a fund for emergency management activities pursuant to the Flood Control and Coastal Emergency Act, commonly known as USACE's authority under Public Law (PL) 84-99. PL 84-99, 69 Stat. 186, codified at 33 U.S.C. § 701n, allows the USACE to undertake activities, including disaster preparedness, advance measures, emergency operations (flood response and post-flood response), rehabilitation of flood damage reduction projects that have been damaged or destroyed by flood, protection or repair of Federally authorized shore protective works that are threatened or damaged by coastal storms, and provisions for emergency water supply due to drought or contaminated source.

A particular flood management system is required to be active in the PL 84-99 program at the time of the flood event to be eligible for Federal funds for rehabilitation, based on USACE inspections. An eligible flood risk reduction system that is damaged by a flood event will be rehabilitated and restored to its predisaster status. Rehabilitation of Federal systems will be Federally funded, and non-Federal systems will rehabilitated with a cost-share between Federal and non-Federal sponsors.

Local flood management agencies have expressed concern about the standards to retain active status in the PL 84-99 rehabilitation program for reasons that include cost to comply with the policy, lack of local O&M funding, potential environmental impacts, conflicting agency requirements, and so on.

3.13.3 Federal Credit for Non-Federal In-kind Contributions

Local agencies interviewed for the Flood Future Report expressed concern that utilizing Section 221 in lieu of Section 104 crediting might slow local projects efforts. Policies regarding in-kind credit consideration for implementation of advance flood risk management measures by a local entity have been amended. New Section 104 applications (Section 104 of the Water Resources Development Act [WRDA] of 1986) will no longer be considered. Rather, Section 221 authority crediting may be used (Section 221 of the Flood Control Act of 1970, as amended by Section 2003 of the WRDA of 2007, codified under 42 U.S.C. § 1962d-5b and ER 1165-2-208 dated February 17, 2012). Section 221 provides a more comprehensive authority for affording such credit to a non-Federal entity.

House at Risk due to bank erosion in Hamilton City

The types of eligible in-kind contributions for which credit could be afforded include planning activities, designs related to construction, and construction. Pursuant to Section 221, credit for allowable in-kind contributions requires an agreement with USACE before work begins. Such agreements include:

- In the case where there is an existing feasibility cost-sharing agreement (FCSA), design agreement, or project partnership agreement (PPA), the sponsor may provide in-kind contributions in accordance with terms of the applicable agreement.
- In the case of projects that are or will be specifically authorized (and no FCSA or PPA exists), an in-kind memorandum of understanding (MOU) for planning may be executed once the USACE South Pacific Division Commander's certification of a reconnaissance report (905b Report) is released. For construction projects, an MOU may be executed once a draft feasibility report has been issued for public review.
- In cases where projects are to be implemented under the Continuing Authority Program or a regional authority (and no FCSA or PPA exists), an MOU can be executed after the USACE South Pacific Division Commander approves the initiation of the feasibility study. An MOU for design and implementation may be executed after the Commander approves the project's decision document.
- Credit for construction of a project, or separable element is limited to credit toward all features of the project covered by specific Project Partnership Agreements or amendment. Excess credit may not be transferred to features of the project not covered by the agreement or to other projects.

Upon completion of the advanced work, USACE would prepare an Integral Determination Report, and the process for determining final credit is undertaken.

3.13.4 Budgeting for Flood Management

Flooding along West Fork Carson River, 1997

Flood risk management in California is a shared responsibility among local, State, and Federal agencies. These agencies face daunting challenges in balancing their budgets. Shortfalls in agency budgets are issues of great concern in planning for implementation of programs that rely on complying with Federal government cost-sharing requirements. Local agencies believe that reductions in Federal spending could signal that USACE and other agencies might not continue to fund flood management projects at the same level. Another issue is that local, State, and Federal budgeting processes do not have the same fiscal calendars and planning horizons.

Local Agency Budgeting Process

Local agency budgets are determined on an annual basis. A local agency budget fiscal year is usually consistent with the State (July 1 to June 30). Typically, local flood management agencies either receive part of the general fund of an agency or rely on assessments to fund projects and O&M. Agencies that are funded through a general fund have to compete with other projects and county needs (e.g., water, sewer, transportation, parks) for funding both capital projects and O&M. Some

agencies are partially funded through development fees or special project assessments that can be limited by assessment zone boundaries. This could be an issue if upstream conditions in one assessment zone cause flooding in a downstream assessment zone, but funds for the upstream zone cannot be used to pay for the downstream improvements. This issue can be significant when a county in a rural assessment zone has upstream problems that result in flooding in downstream urban areas. For most local agencies, revenue is generated by a type of property tax assessment. Unlike other states, California's ability to invest in its infrastructure is limited by voter-approved initiatives, such as Proposition 13 (limiting property tax increases) and Proposition 218 (requiring voter approval for new assessments).

State Budgeting Process

State budgets are determined annually. The governor of California puts forward a budget in January, which is reviewed and then revised in May based on updated State revenue projections. The legislature should adopt a revised budget by June 30. State fiscal year budget is from July 1 to June 30. State agencies such as DWR are primarily funded under the State's general fund but in recent decades have received significant funding for capital projects from bonds such as those from Propositions 204, 12, 13, 40, 50, 84, and 1E, as discussed previously. The funding process varies based on requirements of a given project or program. Some funding is set at the legislative level and others are set at the project level based on program requirements and funding availability.

50th Street Los Angeles County Post Flash Flood, 2005

Federal Budgeting Process

Federal agency budgets are determined annually, and the President's discretionary spending budget is established by policy at the Office of Management and Budget (OMB) to assist in developing priorities for discretionary expenditures in the President's budget consistent with the policy to reduce the national deficit—with a balanced budget as the goal on an annual basis. Federal budget fiscal year is from October 1 through September 30.

USACE Civil Works budgeting has evolved based on several recent and significant shifts in policies and strategic goals. These are:

- Decreased Federal spending is anticipated to continue to decline for the next several years.
- USACE cannot continue to fund all studies or ongoing projects at the same rate with significantly decreased appropriations.
- Completion of studies and projects on time and within budget is critical to the timely upgrading, construction, and maintenance of the nation's infrastructure.

- More public-private partnerships are needed to help finance the modernization of this infrastructure.

USACE's prioritization of studies and projects through business line budgeting, as well as its subsequent funding, will ensure that USACE projects are both cost effective and completed in a timely manner, resulting in:

- Funding fewer studies and projects in any given budget year
- Increased funding over shorter periods for fewer, high-priority projects
- More reliance on public-private partnerships to provide an adequate funding stream over a given period
- More sophisticated prioritization methodologies that focus on economic, environmental, life safety, and social criteria to ensure that the most optimal mix of critical work is funded first

3.13.5 NFIP Modernization

The National Flood Insurance Program, which was instituted in 1968, is managed by FEMA, and requires implementation of prescribed floodplain management practices to obtain Federally subsidized flood insurance. The NFIP requirements have evolved over time as more has become known, and best practices have been added. Early FIRMs did not accurately account for the risk reduction required within 100-year floodplain. Not until the late 1970s were certification requirements for levees developed and implemented with new maps.

Highway 1 Bridge over the Carmel River, March 1995

In recent years, FEMA has been updating the FIRMs for all communities, which involved updating existing levee information to provide risk reduction within the 100-year floodplain. When the new maps no longer recognized levees as providing risk reduction, many communities, particularly in rural agricultural areas, were deemed to be in a 100-year special flood hazard area requiring stricter building standards. Many communities consider that the requirements make it difficult to invest in agriculturally related operations or commercial and housing facilities. In some communities, flood infrastructure might not be FEMA-defined levees, but instead consist of channels and ditches. As a result, some areas that are located behind non-levee infrastructure might be ineligible for the NFIP.

Modernization of the NFIP could be achieved through program reauthorization, statutory amendment, and/or regulatory changes. Goals of modernization could include updated criteria for designations of FEMA flood zones or development of a new agricultural zone. In 2012, the NFIP was reauthorized through September 30, 2017, and includes reforms that are designed to assist local and State agencies in implementing policies to adapt to sea level rise and flooding related to climate change.

4.0 The Solution

Finding solutions to reduce residual flood risk in California is a complex task that will require a mix of both old and new tools and approaches to flood management and funding, evolution of existing planning processes and policies, sustained action, and commitment from agencies at all levels to achieve the desired result of public safety, environmental stewardship, and financial stability in the state. To accomplish these goals, the public, policymakers, and agencies at all levels must work together to address the flood risk that exists statewide. Also, flood management practices must continue to evolve toward IWM, and flood management agencies must be brought into the IRWM process as full partners with other water management agencies. This section of the report will provide a summary of an IWM approach and how it can be used in flood management practices, the importance of taking action now including short-term and long-term solutions, and provides a list of recommendations that can be used as a path forward to reduce California's flood risk.

4.1 An Integrated Water Management Approach

Today, flood management is evolving from narrowly focused traditional approaches toward an IWM approach. Flood management emphasis has shifted to a more integrated approach that includes a mix of multiple strategies, including structural and nonstructural actions and approaches that enhance the ability of undeveloped floodplains and other open spaces to behave more naturally and absorb, store, and slowly release floodwaters during small and medium-sized events. The application of flood management strategies within the context of an IWM approach extends the range of strategies that may be employed over the traditional approach. Additionally, the strategies that could be implemented to manage flood risk within a hydrologic region or watershed will vary depending on the physical attributes of the area, the presence of undeveloped floodplains, the type of flood hazards (e.g., riverine, alluvial fan, coastal), and the areal extent of flooding.

Although the primary purpose of flood management is public safety (i.e., reduce flood risk and reduce the impacts of flooding on lives and property), strategies within flood management can serve many purposes, and flood management is a key component of an IWM approach. Flood management as part of an IWM approach considers land and water resources at a watershed scale, employs both structural and nonstructural measures to maximize the benefits of floodplains and minimize loss of life and damage to property from flooding, and recognizes the benefits to ecosystems from periodic flooding.

Flood management practices benefit from using an IWM approach.

4.2 IWM Definition

IWM is a strategic approach that combines flood management, water supply, and ecosystem actions to deliver multiple benefits. An IWM approach uses a collection of tools, plans, and actions to achieve efficient and sustainable solutions for the beneficial uses of water. An IWM approach reinforces the interrelation of different water management components—such as flood management, environmental stewardship, and water supply reliability—with the understanding that changes in the management of one component will affect the others. This approach applied to flood management looks at the benefits of flooding to natural systems. This approach also promotes system flexibility and resiliency to accommodate changing conditions such as regional preferences, ecosystem needs, climate change, flood or drought events, and financing capabilities.

Los Angeles Department of Public Works Lineman above floodwaters

Using an IWM approach is not a one-time activity. Long-term commitments and alignment among the responsible public agencies are necessary to create sustainable, affordable water management systems. Achieving agency alignment and regional collaboration can be a challenge because an IWM approach requires striking a balance between objectives that are sometimes competing. IWM relies on blending knowledge from a variety of disciplines, including engineering, economics, environmental science, public policy, and public relations.

IWM is an evolving approach embraced by many public and private entities around the world. As a result, nuanced differences exist in definitions of IWM. In addition, agencies use various forms of the term IWM:

- Integrated Regional Water Management (IRWM), which is the application of IWM principles on a regional basis
- Integrated Water Resource Management (IWRM), which is another term used to describe IWM

An IWM approach, however it is named, represents the future of flood management in California, with the ultimate goals to improve public safety, foster environmental stewardship, and support economic stability statewide.

4.2.1 Benefits of IWM

The IWM approach helps deliver more benefits at a faster pace, using fewer resources, than what is possible from single-benefit projects. The benefits of an IWM approach include:

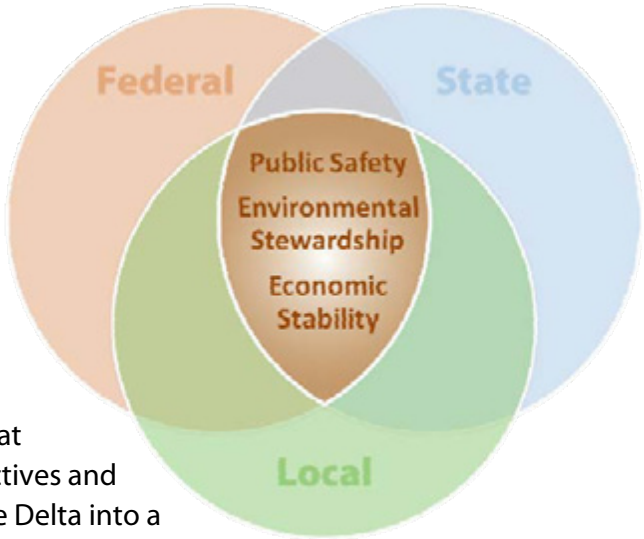
- High value, multiple benefits – An IWM approach combines flood management, water supply, and ecosystem actions to deliver multiple benefits.
- Large range of solutions – An IWM approach relies on bundling solutions from a variety of disciplines, including engineering, economics, environmental sciences, public policy, and public outreach.

- Collaboration and cooperation – Successful implementation of an IWM approach requires public agencies at all levels to work together alongside tribal entities, landowners, interest-based groups, and other stakeholders.
- Regional and systemwide approach – Localized, narrowly focused projects are not the best use of public resources and might have negative unintended consequences in nearby regions. An IWM approach promotes system flexibility and resiliency.
- Array of funding sources – Combining flood management, water supply, and ecosystem actions and beneficiaries could provide access to funding sources not available to single-purpose projects.

4.2.2 Interaction with Existing Programs

DWR and USACE are committed to the IWM approach and have started to implement and support programs to provide multiple benefits. Existing IWM programs include:

- Implementing regional and statewide IWM programs and projects and ongoing regional planning efforts, including IRWM and Central Valley Regional Flood Management Planning.
- Updating the CWP to include a stronger emphasis on flood management efforts throughout the state. The CWP Update 2013 provides the vision for California to manage its water resources through an IWM approach.
- Initiating an IRWM Strategic Plan to document the lessons learned from the different approaches and projects supported by the existing 48 IRWM groups across the state.
- Preparing this Flood Future Report and the CVFPP with associated Conservation Framework, which represent the most comprehensive integrated flood management plan in the recent history of California. The CVFPP integrates flood risk reduction programs with ecosystem restoration and other multi-objective projects, and it provides for flood system resiliency through expansion and extension of the flood bypass system.
- Developing the BDCP, a comprehensive IWM plan that incorporates water supply reliability, biological objectives and ecosystem restoration, and flood risk reduction in the Delta into a comprehensive water, flood, and ecosystem enhancement plan.



As part of the USACE Civil Works (CW) Strategic Plan 2011-2015, the USACE is embracing an overarching strategy that advocates an IWM approach for projects. This plan identifies six cross-cutting strategies to assist with implementing an IWM approach; these strategies are as follows:

- Systems Approach
- Collaboration and Partnering

- Risk-Informed Decision Making and Communication
- Innovative Financing
- Adaptive Management
- State-of-the-Art Technology

4.3 We Must Take Action Now.

California needs significant investment to help prevent flood disasters and to reduce the impacts of flooding. Continued underinvestment in flood management, future uncertainties, as well as development in floodplains will only increase flood management needs and costs. Also, billions more will be spent recovering from an inevitable flooding disaster not to mention the consequences of loss of life, livelihoods, and ecosystems.

Flooding is a reality in California with a significant flood occurring every year in the state since before 1950. Major flood events in the country's recent history provide important lessons for elected and appointed public officials about delaying flood management needs. The financial investment in flood management is a small percentage of the economic impact of a major flood, and an equally small percentage of the money spent recovering from a major flood.

1997 Delta Flooding

Research for the Flood Future Report identified the immediate need for more than $50 billion to complete flood management improvements and projects, including maintenance projects and other identified actions. The research also indicated the need for substantial additional funding to complete flood risk assessments throughout the state and to conduct flood management improvements based on the assessments.

Although it will take many years to reduce flood risk to acceptable levels, steps must be taken now to reduce risks, and to lay the groundwork for long-term solutions.

Some short-term actions do not require substantial additional financial resources:

- Land use planning and decision making must consider flood management. This includes limiting development in floodplains.
- Federal and State agencies must improve planning and permitting processes to allow critical flood management planning, implementation, operation, and maintenance actions to proceed.
- Flood management projects must be broadened to deliver multiple benefits.
- Ongoing public agency outreach programs must inform policymakers at all levels of government about the risks and consequences of flooding.

Long-term solutions require immediate attention:

- Sufficient and stable funding mechanisms must be developed to invest in public safety.
- Public funding for flood management requires alignment among public agencies to deliver the most efficient and economical multiple benefit projects.

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5.0 Recommendations for Managing California Flood Risk

Seven recommendations were identified to address flood management issues and address flood risk in California based on the information gathering and other efforts used to develop the Flood Future Report. All of the recommendations are consistent with an overall IWM approach. The foundation of the IWM planning approach is improved alignment and interaction, which leads to agreement on tools, planning activities, policy and investment actions, and ultimately more beneficial results.

These recommendations are directed to all local, tribal, State, and Federal agencies with responsibility for one or more of the following:

- Agriculture and Agricultural Land Management
- Cultural and Recreation Resources
- Environmental Habitat and Ecosystem Restoration
- Flood Management
- Land Use Planning
- Public Safety
- Water Resources

The recommendations are intended to guide discussions and encourage collaboration among public agencies, elected officials, and key stakeholders to achieve necessary policy reforms and program results. The recommendations (numbered 1 through 7) are organized under the categories of Tools, Plans, and Actions, as shown in Figure 5-1.

Figure 5-1. Organization of Recommendations

The seven recommendations are provided below:

Tools

- **Revised Assessments:** Conduct regional flood risk assessments to understand statewide flood risk.
- **Flood Risk Awareness:** Increase public and policymaker awareness about flood risk to facilitate informed decisions.
- **Flood Readiness:** Support flood emergency preparedness, response, and recovery programs to reduce flood impacts.

Plans

- **Land Use Planning:** Encourage land use planning practices that reduce the consequence of flooding.
- **Regional, Systemwide, Statewide Planning:** Conduct flood management from regional, systemwide, and statewide perspectives to maximize resources.

Actions

- **Increase Agency Collaboration:** Facilitate public agency alignment to improve flood management planning, policies, and investments. Actions include the infrastructure improvements and innovations conducted by flood and water management agencies.
- **Establish Sufficient and Stable Funding:** Establish sufficient and stable funding mechanisms for projects/programs to reduce flood risk.

Destroyed Highway 101 Bridge over the Eel River, 1955

The objective of these recommendations is to facilitate improved public safety, environmental stewardship, and economic stability by reducing flood risk in California. The recommendations in this attachment are high-level strategies, the implementation of which is intended to be worked out in collaboration with local, tribal, State, and Federal agencies, as well as other stakeholder groups. These strategies are examples of actions that can be undertaken but do not represent the full range of actions. These recommendations and the processes used to develop them are described l in *Attachment J: Recommendations to Improve Flood Management in California*.

Table 5-1 is a matrix showing linkages between the recommendations and major findings from the other attachments.

Table 5-1. Matrix of Recommendations versus SFMP Findings

Flood Future Report Findings	Risk Assessments	Flood Risk Awareness	Flood Readiness	Land Use Planning	Regional, Systemwide, and Statewide Planning	Agency Collaboration	Sufficient and Stable Funding
Inadequate understanding of flood risk	●	●					
Inconsistent flood risk assessment method	●						
Few systemwide risk assessments have been completed	●						
Lack of understanding FEMA levee accreditation process	●	●					
Insufficient data and mapping	●	●	●				
Lack of climate change guidance	●	●	●				
20% of California population exposed to flooding within the 500-year floodplain	●	●	●	●			
Over $580 billion in assets exposed to flooding within the 500-year floodplain	●	●	●	●			
Loss of function of critical facilities could have catastrophic economic impact	●	●	●	●			
One-size-fits-all approaches do not work in California	●	●	●	●			
Need improved emergency management coordination			●				
Local agency understanding of emergency management processes need improved emergency management			●				
Disconnect between land use planning and flood risk		●	●	●		●	
Local agency decision makers do not understand flood risk		●	●	●	●		
Inefficient communication between and within flood management agencies			●	●	●	●	
Flood agency does not feel like full partner in IRWM process					●	●	
Systemwide approach to flood management leverages resources					●	●	

Table 5-1. Matrix of Recommendations versus SFMP Findings

Flood Future Report Findings	Risk Assessments	Flood Risk Awareness	Flood Readiness	Land Use Planning	Regional, Systemwide, and Statewide Planning	Agency Collaboration	Sufficient and Stable Funding
IWM can provide new funding mechanisms for projects					●	●	
Changing regulatory requirements make O&M difficult					●	●	
Diverse governance structures makes flood management difficult					●	●	
Local agencies are facing conflicts in permitting requirements					●	●	●
Local agencies need help communicating needs to Federal agencies		●			●	●	●
Flood management agencies face funding challenges						●	●
Small agencies lack resources to apply for grants						●	●
Local agencies lack funding for O&M on existing infrastructure						●	●
Local agency funding is limited by Propositions 13 and 218						●	●
Flood management funding is reliant on bond funding						●	●
Project needs exceed available funding						●	●

1 Conduct regional flood risk assessments to better understand statewide flood risk

Identifying flood risks is an important first step toward reducing risk and prioritizing flood management infrastructure needs in California; however, few detailed risk assessments have been completed. This often causes agencies to default to overly simplistic methods or leave their flood risk undetermined. Several complex methods are currently used to assess flood risk, which results in confusion and inconsistent assessment of risk. A consistent method of assessing risk would be more cost effective and result in better understanding of risk.

Goal: Consistent and locally appropriate assessments of flood risk to help local governments make informed decisions about priorities for land use, emergency response, ecosystem functions, and flood management projects throughout the state.

Strategies:

- **Identify regional methods and evaluate flood risk to prioritize areas where flood risk exists.**

  Standard methods to evaluate flood risk in California must be identified for each region of the state. Technical support for risk evaluations and data collection are needed to support the efforts of local agencies. "One-size-fits-all" approaches do not work for flood risk management due to the different climates, geographies, and types of flooding that exist in California. Each region of the state experiences flood risk differently. As described in *Attachment G: Risk Information Inventory*, different types of risk assessments are performed statewide. For example, FEMA, CalEMA, and many local agencies assess flood risk in terms of FIRMs, as well as in terms of the 1 percent annual probability (100-year) and 0.2 percent annual probability (500-year) flood events. However, one of the primary methods DWR and the USACE uses to assess flood risk is in terms of EAD, which is a more rigorous risk assessment methodology that requires data, expertise, and other resources not available to many local agencies.

  Agencies in each region of the state need to collaborate to identify risk assessment methodologies that can meet the needs of agencies at all levels and be cost effective. Varying levels of assessment are needed to meet the resources and risk acceptance levels in different areas of the state. For example, more detailed levels of assessment might be needed in highly urban areas where more assets would be at risk. However, risk assessment methodologies need to be compatible so that results can be used by agencies across the state to assess and prioritize flood risk.

Strategies (continued):

- **Assist in identifying regional flood risk reduction goals and corresponding acceptable levels of residual risk throughout the state.**

  In California, flood risk reduction needs vary across the state. Appropriate levels of risk reduction will vary based on the number of lives and amount of property at risk, degree of urbanization, flood types, number of critical facilities, and level of acceptable risk for the region. National and international reliance on California products and facilities must be considered in identifying an appropriate level of risk reduction.

  Determination of the level of risk reduction should be locally driven, with expertise and technical resources provided by Federal and State agencies. Currently, most agencies use a 100-year event as the basis for assessing risk and constructing facilities; however, in highly urban areas with a high risk of flooding, this level of risk reduction might not be adequate. In other more rural areas of the state where flooding is intermittent, the existing level of risk reduction might be adequate. Residents and local decision makers must understand flood risk, as well as assist in identifying the acceptable level of risk for their region. Climate change should be included in this assessment.

- **Identify opportunities to restore or maintain natural systems.**

  Flood risk evaluations should explore opportunities to restore or maintain the function of existing natural systems. Development in floodplains can permanently alter natural floodplain functions, destroy the habitats of sensitive species, and reduce the beneficial connections between different types of habitat and adjacent floodway corridors.

  Effective floodplain management finds the appropriate balance between providing for public safety and protecting sensitive ecosystems. Floodplains that function well not only provide habitat for a significant variety of plant and wildlife species but also provide natural attenuation of flood flow peaks. Flooding in natural functioning floodplains can recharge groundwater basins, improve water quality, and control erosion. Local, State, and Federal agencies should collaborate when performing risk assessments and during other planning efforts to identify, protect, and restore natural ecosystems.

Northern California Flooding, 1997

Strategies (continued):

- **Assist agencies in assessing the impacts of climate change and sea level rise.**

  Currently, information about climate change and sea level rise has not been developed for many areas of the state; additionally, many local agencies do not know how to access or use available information. Using such information is mandatory under some planning programs because certain conditions could have an impact on land use or other planning decisions. Currently, information related to sea level rise and climate change is being developed and refined by a number of different agencies, including the California Geological Survey, DWR, California Coastal Commission, and the Ocean Protection Council. Due to the spatial coverage and availability of these data, individual local agencies might have difficulty in dedicating resources to coordinate with the agencies involved for the use of data. Consolidating information will facilitate its dissemination to regional or local agencies and will provide for better communication and cooperation for data use. Federal and State agencies should assist local agencies in identifying and compiling data.
  Climate change materials could be made available electronically on DWR's website via the Water Data Library (WDL), the California Data Exchange Center (CDEC), or another source.

Coastal Flooding in Northern California

Tools

2 Increase public and policymaker awareness about flood risks to facilitate informed decisions

Policymakers and the public have varying levels of understanding about the risks and consequences of flooding. Historically, decisions have been made that lead to putting people and property at increased risk.

Goals: Local, State, and Federal officials support policies, programs, and financing strategies to reduce flood risk in California. California voters support funding mechanisms to reduce flood risk. California residents in flood-prone regions support local flood preparedness efforts and develop personal preparedness plans.

Strategies:

- **Develop consistent messaging of local, State, and Federal initiatives for public awareness of flood risks.**

  Public agencies, using common language and outreach tools, will help avoid public confusion and will maximize limited financial resources. There are several existing programs that inform communities about ongoing flood management activities such as FloodSmart, FloodSAFE, Risk MAP, the National Flood Risk Management program, and other local efforts. Residents and decision makers in flood-prone communities typically are presented with flood risk as it relates to the NFIP, and participants might not understand the risk to facilities or potential impacts to their neighborhoods. Increased coordination and alignment of these efforts could leverage resources to expand awareness of flood risks and reduce confusion about flood risk terminology.

  Materials should be developed to specifically address understanding not only of flood risk but also how land use and other planning decisions directly impact this risk. Messages need to be tailored to specific audiences so that the public understands the impacts of local decisions. In addition, different types of materials or messages might be needed for different areas of the state based on location, whether the area is rural or urban, and local flooding circumstances. Local agencies should help craft emblematic messages about risk for their communities, such as how flooding could impact regional infrastructure, how deep flooding would be at a specific location, or the economic impacts of flooding in a region. Some local agencies might need additional assistance because they do not have the expertise or resources to perform outreach.

Strategies (continued):

- **Provide State and Federal outreach program tools, templates, and other resource materials to local agencies.**

  Sharing resources saves time and money, and will facilitate public awareness efforts in many regions. Sharing resources will foster consistency among outreach programs. Coordination of resources, studies, and findings would reduce duplicative efforts, as well as reduce the potential for confusing or contradictory messages about flood risk. In addition, Federal and State agencies should coordinate with local agencies since the local agencies are often better suited to understand how best to reach out and inform their communities. Metrics should be put in place to determine the effectiveness of messages and outreach efforts. Currently, the USACE and FEMA are required to report findings on outreach activity metrics on a quarterly basis.

- **Catalog, provide, and promote online information resources about flood risk programs, grants, and other related topics.**

  A lot of information is available online about flood management, including data, case studies, budget information, and planning tools. Making agencies aware of and providing easy access to this information will improve flood management at all levels of government. To make this information useable, it is important to develop the ability to store and manage flood risk information gathered statewide in a centralized database and website. Currently, DWR utilizes the WDL, CDEC, and Flood Emergency Response Information System (FERIS) to facilitate dissemination of flood information.

  - The WDL is a searchable Geographic Information System (GIS) interface on the Internet. WDL allows users to access information about monitoring gauges, groundwater data, and water quality.
  - CDEC provides a centralized location to store and process real-time hydrologic information gathered from different contributors statewide.
  - FERIS is a geospatial information system that allows for integration of existing CDEC systems with real-time data collection and data exchange.

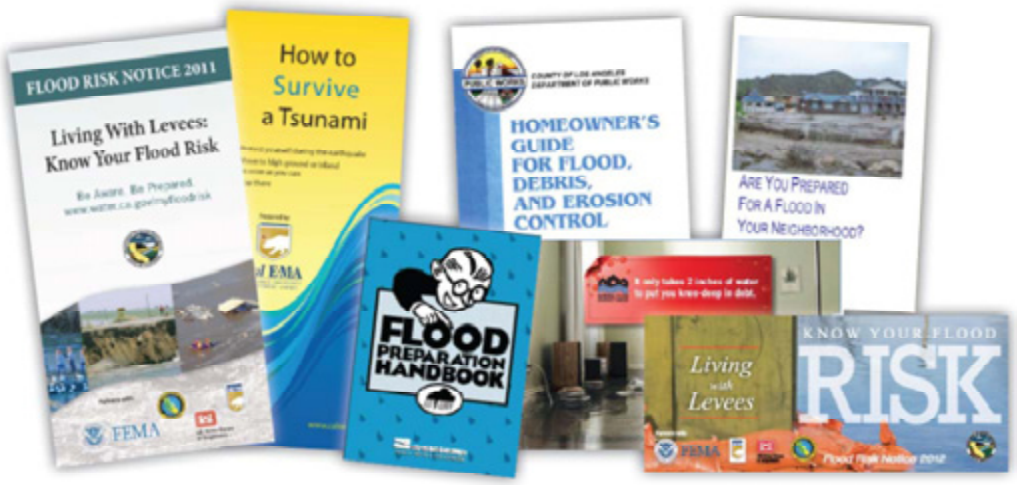
  CDEC should be used to forecast coordinated operation of reservoirs, the CVFPP, and new systems and sources of information should be coordinated as they are developed. FERIS was developed for flood operations in California. These tools could be expanded, or new tools could be developed, to store data and information identified and developed as part of the data needs assessment. Having a website would be a valuable tool for key decision makers and would provide an excellent resource for local agencies to learn more about other agency projects and approaches to managing flood risk.

Tools

Strategies (continued):

- **Share research data and other information between public agencies in a timely fashion.**

  Sharing information fosters collaboration and cooperation between agencies, which helps save time and money as regional plans and projects are developed. Flood management at all levels is involved in developing data, mapping, studies, and designs of flood infrastructure. Improving coordination and alignment between agencies will improve sharing of this information, particularly if agencies are working together on IWM projects.



A Sample of Existing Flood Awareness Information in California

3 Increase support for flood emergency preparedness, response, and recovery programs to reduce flood impacts

Flood emergency management is a cost-effective, nonstructural tool to reduce flood risk. Flood emergency preparedness, response, and recovery are often fragmented between local agencies within a region and even within different departments of a single agency. Funds for emergency planning are often reduced during difficult or contracting budget cycles.

Goal: Effective and comprehensive flood emergency preparedness, response, and recovery at all levels of government.

Strategies:

- **Provide funding specifically for increased coordination among responders, facility managers, planners, and representatives of State and Federal resource agencies to improve readiness.**

  Pre-event coordination improves emergency preparedness by identifying and reinforcing areas of expertise, available resources, and planning agreements. Currently, local, State, and Federal agency flood managers coordinate through regional preseason meetings, which are held around the state. However, many local agencies do not have adequate funding to participate in these meetings. These meetings focus on weather conditions, potential flood conditions, flood-fighting methods, proper coordination among local-State-Federal agencies, and DWR Flood Emergency Response (FloodER) activities. In the past, the meetings have been well attended, but attendance could be expanded to include local agency planning staff. This would facilitate better alignment within and between local agencies statewide.

  In addition, if adequate funding were provided, these meetings could convene more frequently to improve regional coordination between agencies and to provide a forum for sharing information and best practices, and for disseminating guidance for flood preparedness, response, and recovery. Specific activities that could be facilitated through these meetings include guidance on how to prepare for flood fights, how to develop an emergency management plan, and how to complete requests for disaster recovery funding, including PL 84-99 requests and FEMA claims. Funding also could be useful to support other types of flood emergency readiness and coordination.

Strategies (continued):

- **Develop or improve Flood Emergency Management Plans.** Consistent emergency plans based on the State Emergency Management System will help local responders work together to solicit and accept State and Federal assistance during emergencies.[4] Hazard mitigation planning is performed at a local, State, and Federal level. State Hazard Mitigation Plans (SHMPs) are required at a State level to continue Federal disaster assistance funding. In California, Local Hazard Mitigation Plans (LHMPs) have been developed by 37 counties, almost 300 cities, and more than 360 special districts. These plans are living documents that analyze risk from natural hazards, coordinate available resources, and implement actions to reduce or eliminate risks. State and Federal agencies should work with local agencies to use HMPs, as well as other information, to complete flood emergency management plans. To encourage proper emergency preparedness planning for flood events, grant funding and other cost-sharing could be linked to completion of emergency management plans and HMPs. Also, emergency management plans could be encouraged in Federal feasibility studies as a nonstructural measure to reduce risk. State and Federal agencies also could promote completion of these plans by providing coordination and technical assistance to local agencies for preparation of the HMPs. In addition, HMPs could be reviewed by local, State, and Federal flood management agencies, through enforcement of existing zoning and subdivision regulations and permits.

Flood Fighting in Northern California, 2004

[4] USACE requires the adequacy of existing or development of a comprehensive Flood Warning Emergency Evacuation Plan for such Federal decision documents where public safety is at issue.

Strategies (continued):

- **Conduct flood emergency preparedness and response exercises statewide and increase participation among public agencies at all levels in flood-fight training.**

  Regular training, tabletop drills, and functional exercises are necessary parts of disaster preparedness. In some areas of California and for some types of floods (e.g., tsunamis), there are detailed flood emergency preparedness and response plans. However, for some types of flooding (e.g., alluvial fan and coastal), less is understood about how to plan for, prepare for, and respond to these floods. This strategy would build upon ongoing efforts to understand alluvial and coastal flooding to determine how to develop predefined emergency response plans.

  In addition, existing programs could be expanded by conducting more training sessions and working to expand local agencies' knowledge of flood emergency preparedness, response, and recovery. These programs could work with CalEMA to organize annual flood-fight response exercises statewide similar to CalEMA's Golden Guardian program, which simulates disaster exercises.[5] For example, in 2011, the Golden Guardian program held a full-scale exercise simulating a major flood in the Inland Region of California. It focused on testing flood managers' preparedness, response, and recovery capabilities.

- **Identify data and forecasting needs for emergency response and water management.**

  Accurate and timely forecasts for flood events can increase warning time, save lives, and reduce property damage. Additional data will help improve the readiness and response to floods. Agencies statewide need additional flood management information, such as from monitoring gauges and mapping. This information should be used for a wide range of activities—from planning to responding to flood events. These data needs go beyond emergency response to information needed for assessing risk. The SFMP teams collected detailed information about flood risk but did not identify missing data requirements or detailed information about emergency response. To obtain a complete picture of what is needed statewide, an assessment of existing emergency management data and tools will be needed. An assessment would focus on emergency response data/forecasting needs and identify areas of overlap where data or tools could be used for other planning purposes. These needs include investment in monitoring gauges, forecasting points, flood warning systems, and other technologies. Once the needs are assessed, investment options could be identified to prioritize the needs. For this effort to be successful, funding will be needed for acquisition of new data and tools.

[5] Note: The next flood-specific Golden Guardian exercise is planned for 2015. The exercise will simulate a catastrophic flood in southern California and will focus on response and recovery capabilities.

Plans

4 Encourage land use planning practices that reduce the consequences of flooding

Development in California has increased in areas that are at risk for flooding. Some local land use agencies experience pressure to foster economic growth by approving development in areas with high exposure to floods.

Goal: Reduced risk to people, property, and economies in floodplains.

Strategies:

- **Work with organizations that represent flood management and land use professionals to develop planning principles that will help decision makers determine if property is at risk for flooding.**

  Promote these principles as "best management practices" (BMPs) to increase wise land use planning. Similar to other statewide programs, BMPs could be developed for development within or adjacent to a floodplain. This might include levee setbacks, or employing riparian corridor policies or greenspace ordinances into local land use planning decisions. The BMPs could be developed at the State level to address a variety of applications and then be distributed to all flood risk managers to use as guidelines for future development on lands in floodplains. BMPs for flood-compatible land use could be developed by Federal, State, and local agencies. These BMPs could adopt the practices described in Federal Executive Order 11988, which requires Federal agencies to avoid to the extent possible the long- and short-term adverse impacts associated with the occupancy and modification of floodplains and to avoid direct and indirect support of floodplain development wherever there is a practical alternative. The BMPs could require that all projects proposed within a floodplain demonstrate practical alternatives to development in the floodplain, along with an evaluation of impacts of each alternative. If impacts within a floodplain cannot be avoided, the applicant would have to demonstrate how to mitigate the impacts or restore the floodplain to the extent possible. The BMPs would encourage development of a standard level of risk reduction based on the people and property at risk in the region. The level of risk reduction would be determined by local agencies but would be reviewed by local, State, and Federal flood management agencies.

Strategies (continued):

- **Facilitate regular coordination at all levels among land use planners, resource managers, floodplain managers, and emergency response managers.**

  Coordination among planners, flood managers, resource managers, and emergency response managers can help to reduce impacts of flooding and improve public safety. Planning departments in most local agencies are tasked with approving planning proposals on a project-by-project basis. In most communities, if the development is not within the FEMA flood hazard zone or within the jurisdiction of a Federal agency, or if the project owner is not seeking financial support from the State, then flood managers typically do not get involved in land use decision making. This can result in development that increases the impact or required infrastructure to manage stormwater and/or floods.

  Facilitating improved alignment and coordination between land use and flood management would result in better understanding of flood risk and potential impacts to proposed developments, as well as improved decision making. Specifically, flood risk information has the potential to influence land use policy decisions related to developing and expanding communities within a floodplain, which would result in reductions to flood damage claims and long-term O&M costs on projects.

  At the planning stage, additional measures might be incorporated into the initial proposed projects that could provide community benefits, such as setback areas that act as greenways or trails, and greatly reduce the need to retrofit or replace undersized infrastructure in the future. Too often, regional and land use policymakers realize flood risk and economic losses only after a damaging flood event.

  Regional and local land use policymakers could make better informed planning decisions if the hazards of flooding are described in advance in terms of loss of life, loss of functionality, and potential economic and environmental impacts. Federal and State agencies should take the lead in hosting workshops, meetings, and other forums to promote coordination and information sharing between planners and flood managers. These activities could be coordinated with emergency management workshops and training activities.

Strategies (continued):

- **Link funding for flood management improvements to implementation of BMPs for floodplain management.**

  Fiscal incentives can help improve land use planning to reduce risks to people and property, as well as to maintain and restore natural functions of floodplains. Local planning decisions and land use planning policies are typically handled at the local level. A variety of statutes govern flood management associated with land use planning; however, in general, flood managers are not included in land use decisions.

  BMPs that encourage fully integrated land use and flood management decisions should be incentivized. Also, development of model land use ordinances and revisions to building codes for development of critical facilities within a floodplain are other tools that could be used. Providing incentives for local agencies to integrate flood risk into planning efforts is an approach that should be used to encourage improved land use decisions that reduce flood risk. This would be accomplished by linking grant funding (or other cost-share funding) to the implementation of flood management planning guidelines or BMPs that encourage integrated land use and flood planning decisions.

High Water in the Sacramento-San Joaquin Delta, 1997

5 Implement flood management from regional, systemwide, and statewide perspectives to provide multiple benefits

Historically, flood management projects have been developed primarily on a site-by-site basis. This approach does not consider California's complex regulatory, permitting, and water management environment. It is important for flood management agencies and water agencies to work together to develop regional solutions that produce integrated benefits.

Goal: Agencies at all levels of government use an IWM approach for flood management.

Strategies:

- **Identify regional flood planning areas.**
  Specific regions for flood management planning could be established throughout the state to encourage agency coordination between flood management agencies. Boundaries for these regions could be watershed based, systemwide, and consistent with existing State and Federal agency boundaries, including existing IRWM planning areas. IRWM is the application of IWM principles on a regional basis in California. Regional flood planning areas could be developed to promote regional or systemwide planning for flood management. These areas would enable the complex array of flood management agencies to begin working together to resolve common flooding, permitting, planning, and funding problems on a regional or systemwide basis. Ultimately, these planning regions and IRWM groups might coalesce into a single planning entity; however, initially these regional flood planning areas need to be defined and based upon flood management considerations. New regional flood planning areas should be established, adhering to the following principles:
  - The regions should promote system- or watershed-scale planning; therefore, they should be hydrologically based (i.e., based upon CWP hydrologic regions or Hydrologic Unit Code [HUC] 8 watersheds).
  - To the extent possible, the regions should respect existing, established planning areas such as those associated with IRWM (i.e., Proposition 84 funding regions).
  - To the extent possible, the regions should incorporate key agency organizational boundaries (i.e., USACE district boundaries).

Strategies (continued)

The local agencies within each established region, working with DWR and USACE, should make changes to coordinate planning activities on a regional scale to accomplish a number of objectives, including:

- Assistance with the implementation of the Flood Future Report recommendations
- Development of a plan for the region
- Development of a finance plan to prioritize needs and financial assistance requests
- Identification of key issues/obstacles to planning, funding, and project implementation
- Coordination with IRWM planning groups, particularly in relation to grant acquisition activities

The establishment of regional flood planning areas statewide would be similar in form to the establishment of the CVFPP Regional Flood Management Planning (RFMP) areas. The existing RFMP areas are similar in form but smaller in size and scope than the proposed flood management regions. For example, the RFMPs cover smaller geographic areas, so these areas would be considered subareas under the SFMP.

- **Prioritize flood management projects in each region.**

  Regional priorities for flood management actions can foster IWM actions and make the best use of funding. Flooding happens locally, and local agencies have the best understanding of the flood risk for a specific area. For this reason, local and regional agencies are better informed to prioritize flood management needs; however, priorities would have to be established using a set of standard statewide criteria, which would be developed collaboratively by local, State, and Federal agencies as part of Recommendation 6. Local agencies would work first at a local level to determine priorities for flood management and then would work with other regional agencies to determine regional or systemwide priorities. Ultimately, these local or regional priorities would be compiled at a statewide level to establish flood management priorities.

- **Expand State and Federal processes for developing, funding, and implementing flood management projects with an integrated approach in each region.**

  Encourage and incorporate project components to achieve a broad range of objectives. Develop common terminology for State and Federal programs to help grantors and grantees understand the IWM approach.

Strategies (continued):

- **Improve coordination between programs and entities for water management and flood management planning.**

  State and Federal funding requirements must include coordination between flood management and water management programs. Improving coordination between regional water management and flood management planning is a key strategy to increase implementation of IWM projects. Existing planning groups and forums should be utilized to the extent possible. By coordinating water and flood management planning with balanced representation, a common understanding of flood management, water supply, water quality, environmental stewardship, public safety, and economic sustainability factors would be developed. Where possible, policy changes that promote this holistic approach to IWM should be proposed and sponsored (for example, changes to existing IRWM legislation).

- **Link funding to an IWM approach.**

  Incentivizing an IWM approach with State and/or Federal funds will encourage local agencies to consider systemwide, multibenefit projects when developing options for flood management. State and Federal agencies historically have partnered with local agencies to help fund flood management projects in California. An IWM approach to projects could leverage available funding and develop solutions that address multiple objectives. In addition, multi-stakeholder partnerships and multibenefit projects could spread costs among project partners, as well as leverage a broader set of funding sources.

  Coordination among diverse agencies and entities is the key to successful planning and implementation of an IWM approach. Therefore, it is important to develop common terminology for State and Federal programs for project proponents to maximize funding from all sources. Coordination should be expanded to include outreach beyond project proponents to other affected stakeholders. For example, improving coordination to landowners impacted by a multibenefit project could increase the likelihood of implementation by reducing potential opposition.

Vic Fazio Wildlife Area at South End of Yolo Bypass

Actions

6 Increase collaboration among public agencies to improve flood management planning, policies, and investments

California has more than 1,300 agencies with direct responsibility for flood management. This complex governance situation makes agency coordination fragmented and difficult. California's flood and water management agencies oversee the operation, maintenance, and improvement of vital infrastructure and facilities within agency boundaries. This traditional "silo" approach is inefficient and expensive. Improved agency collaboration and alignment will provide a variety of benefits, including fostering innovative solutions to problems, improving planning and permitting processes, developing high-value multibenefit projects, and prioritizing investment needs.

Goal: Improved coordination and alignment among local, State, and Federal public agencies, providing increased effectiveness and efficiency in all aspects of flood management.

Strategies:

- **Establish regional working groups to foster efficient permitting, planning, and implementation of flood management projects.**

  Local, State, and Federal agencies must work together to develop solutions and work through regional issues. Agencies should work together to incentivize participation of resource agencies in regional working groups that focus on planning and implementing flood management projects. These working groups would provide a forum to prioritize projects, facilitate discussions about permitting, and address regional issues. The forums would foster a process tailored for specific regions and address specific flood management and regulatory issues unique to those areas. Funding could be provided to resource agencies to ensure participation in these forums. Success metrics would be established and tracked, and ongoing funding for participating agencies would be linked to demonstrated progress, such as the number of projects permitted.

  There are several existing, working forums that assist with agency coordination, which could serve as models or examples to assist with formation of the regional working groups as described. These include:

  - California Coastal Sediment Management Workgroup (CSMW)
  - California Levee Roundtable
  - Dredged Material Management Office (DMMO)

Strategies (continued):

- **Provide funding and in-kind credit programs for regional planning.**
  State and Federal agencies should develop financing program guidelines to encourage local agencies to collaborate on multibenefit projects. Programs such as the subventions funding and grant funding could be realigned to direct more funding toward multibenefit or watershed-based projects.

  Currently, DWR's Statewide and Delta Subventions Programs are operated on a "first-come, first-served" basis. In addition to those programs, in-kind service credits could stipulate the requirement of regional, systemwide, and statewide planning. Also, grant funding processes and criteria should be simplified and standardized to reduce the level of effort and expertise required to apply.
- **Develop a methodology to prioritize and implement flood management investments.**
  Current funding criteria and processes are complex and hamper the development and implementation of priority projects. A new methodology should be developed and used by local, State, and Federal agencies to establish investment priorities across the state. Alignment among current and future local, State, and Federal resources is needed to implement priority flood projects and programs.

  Developing a flood management funding priority represents a shift from the status quo. Currently, funding levels are identified, and then projects are identified to use this funding. Prioritizing projects will change this process by first identifying needs then seeking the funding to meet these needs.

  To make this new paradigm successful, local, State, and Federal agencies must work together to develop criteria for project prioritization. These criteria must have the capability of working across all areas of the state, with different types of flooding, and with different types of projects. Once the criteria are developed, projects would be prioritized at a local level, then at a regional or systemwide level. Ultimately, the prioritization will be used to establish statewide priorities for flood management in California. Having a statewide set of flood management priorities would articulate needs to State and Federal decision makers responsible for setting investments.

Orange County, California, 1969

Actions

Actions

7 Establish sufficient and stable funding mechanisms to reduce flood risk

The backlog of identified flood management projects is primarily due to lack of funding, which puts the State's economy, environmental resources, and millions of people at risk. Prioritizing and communicating flood management investment needs will help generate support for increased funding. Sustained investment in California's flood management systems should help avoid much larger future costs for flood recovery.

Goal: Funding to implement necessary flood management programs and projects in California.

Strategies:

- **Assess the applicability of all potential sources and propose new options to provide sufficient and stable funding for flood management.**

  Local and State flood management partners should work together to propose changes or alterations to local funding methods. For example, changes to current law (e.g., Proposition 218, the 1996 Right to Vote on Taxes Act) could include reclassification of flood management agencies to be exempted public safety utilities or the establishment of regional assessment districts, in areas where such districts do not exist. Implementing these changes would help local agencies develop additional funding sources for O&M and capital projects. Regional assessment districts should be established where needed to support flood management.

  Identifying new sources of funding for flood management projects is critical to being able to meet future flood management needs. To identify sources of funding, all existing funding sources should be assessed by a wide range of flood and financial experts, including university partners and corporate experts. This assessment should be used to identify the best methods to fund future projects.

- **Improve and facilitate access to information about State and Federal funding sources.**

  A central online resource catalog should be developed to describe the different funding programs and provide guidance to local agencies on how to apply for funding. All potential funding sources for flood management funding should be identified and information compiled. This information should be used to develop an online "how-to" guide explaining how to apply for funding from these programs. The guide would describe current programs, their purposes, general requirements (eligibility), resource contact information, potential funding levels, and links to websites.

Strategies (continued):

Such guidance could assist tribes, rural-urban, rural-agricultural areas, and disadvantaged communities with access to grant opportunities. This effort would include outreach to agencies to provide information and expertise in how to apply for grant funding and how to prepare solicitation packages. Focused outreach would build upon existing Federal and State programs that are ongoing. Workshops would be conducted to disseminate information statewide.

- **Increase funding for flood management projects.**

Local and State agencies must work together to advocate for sufficient and stable funding for regionally based IWM projects. Additional funding sources are needed to fund flood management projects and would include maximizing existing funding and identifying ways to minimize project costs, as well as researching for new funding sources.

Existing funding can be maximized by implementing systemwide approaches and multibenefit projects. Using systemwide approaches enables projects to seek funding from multiple sources and to share costs among local agencies. Regional flood planning areas should be used to identify and prioritize these systemwide projects. Project prioritization should be used by Federal and State agencies to assess flood risk priorities statewide.

Project costs can be reduced by working with resource agencies to improve project permitting, which could result in substantial cost savings. Local agencies could share costs with other entities (agencies, stakeholders groups, or private entities) that benefit from a project. Cost allocation would be developed on a case–by-case basis. Effective land use planning is another way to reduce future flood management costs by providing adequate natural systems that can accommodate floods.

California State Capitol

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6.0 The Path Forward

USACE and DWR believe that water management solutions must be crafted with the understanding that flood risk, ecosystem health, water supply reliability must be inextricably linked to achieve short-term success and long-term sustainability. Integrated solutions for California water issues must be based on developing and maintaining sustainable systemwide flood risk reduction where public safety is a primary goal.

A comprehensive, multi-stakeholder, integrated, and sustainable program for flood and water management is needed for the State to overcome twenty-first century water and flood management issues. A sustainable flood and water management approach would recognize the:

- Interconnection of flood risk management actions within broader water resources management, ecosystems, and land use planning
- Value of coordinating across geographic and agency boundaries
- Need to evaluate opportunities and potential impacts from a system perspective
- Importance of environmental stewardship and sustainability
- Need for system flexibility and resiliency in response to changing conditions, such as climate change and population growth

Efforts for reduction of future flood risks will require unprecedented alignment and cooperation among agencies. California must develop long-term, integrated approaches to flood risk.

Solutions must be crafted in the context of IWM. IWM relies on the blending of knowledge from a wide variety of disciplines, including engineering, economics, life sciences, and public policy and outreach. That is why it will be imperative that coordination does not occur in silos, but rather across all tools, plans, and actions to have meaningful results. IWM for California will require regional planning and forums to overcome many of the institutional barriers and to reduce the regulatory and administrative burden to operate, maintain, and improve the State's flood infrastructure.

The IWM approach is not a one-time activity. Creating sustainable, affordable water resource systems requires long-term commitments that have adaptive capacity to adjust to factors such as financing capabilities, changing political objectives, climate variability, and flood or drought events. Fortunately, many agencies with flood responsibilities already participate in forums that have begun to address California's water resource challenges using an IWM approach.

Sacramento River

Through this report, USACE and DWR commit to work together in the interest of public safety to plan, build, operate, and maintain structural and nonstructural solutions that reduce flood risks, enhance environmental stewardship, and provide the framework for long-term economic stability.

6.1 Approach to Implementing the Recommendations

In Chapter 4, seven recommendations were identified to address flood management issues and address flood risk in California based on the information gathering and other efforts used to develop this Flood Future Report. The recommendations are organized under the categories of Tools, Plans, and Actions:

Tools

- **Revised Assessments:** Conduct regional flood risk assessments to understand statewide flood risk.
- **Flood Risk Awareness:** Increase public and policymaker awareness about flood risk to facilitate informed decisions.
- **Flood Readiness:** Support flood emergency preparedness, response, and recovery programs to reduce flood impacts.

Plans

- **Land Use Planning:** Encourage land use planning practices that reduce the consequence of flooding.
- **Regional, Systemwide, Statewide Planning:** Conduct flood management from regional, systemwide, and statewide perspectives to maximize resources.

Actions

- **Increase Agency Collaboration:** Facilitate public agency alignment to improve flood management planning, policies, and investments. Actions include the infrastructure improvements and innovations conducted by flood and water management agencies.
- **Establish Sufficient and Stable Funding:** Establish sufficient and stable funding mechanisms for projects/programs to reduce flood risk.

By developing the necessary tools, preparing thorough plans, and formulating and implementing actions, results can be achieved (see Text Box 6-1 for definitions).

Textbox 6-1: Definitions of Recommendation Categories

Tools

Data, models, and assessments needed for decision making in all aspects of flood management. DWR and USACE continue enhancing and sharing technical resources (tools) across all programs and projects. This includes flood, environmental, and water management data gathering, modeling, and the technical aspects of flood readiness and emergency response. Technical and modeling information help inform thorough and thoughtful planning, along with accurate design of flood management facilities.

Plans

Plans utilize information provided by tools, as well as input from stakeholders to guide the development of the flood management strategies. Plans take into account near- and long-term actions, as well as any additional considerations, such as multiple benefits, environmental concerns, overall water management, and climate change, to formulate long-lasting resilient strategies. Plans include identifying and evaluating possible multibenefit projects and the most effective means of implementing projects using an integrated, collaborative approach.

Actions

Informed by tools and guided by plans, actions include activities that fund, manage, and oversee implementation of the projects. Actions also include fostering innovation and developing agency alignment to improve flood management policies, planning, governance, and investments. Actions based on IWM principles and thorough planning efforts will provide the most benefit to Californians.

Results

Robust tools, thorough planning, and integrated actions deliver results that provide value to California's residents, environment, and economy. Results are tracked using performance measures and sustainability indicators that help improve investment performance and increase flood management benefits.

6.2 Recommendations Lead to Results

The objective of the recommendations identified in this report is to improve public safety, environmental stewardship, and economic stability by reducing flood risk in California. The recommendations are high-level strategies, the implementation of which is intended to be worked out in collaboration with local, tribal, State, and Federal agencies, as well as other stakeholder groups.

As described in the recommendations, the path forward to effective results is charted using tools, plans, and actions.

The recommendations outlined in this report are designed to deliver measureable results to achieve public safety, environmental stewardship, and economic stability. These results include:

- Reduced risk and consequences of flooding
- Informed decisions for flood risk made by policy leaders and the public
- Protected ecosystems and preserved floodplain functions
- Multiple benefits delivered for projects funded by State and Federal agencies
- Improved flood management governance and policies
- Identification of statewide investment priorities
- Sufficient and stable funding for flood management

6.3 Next Steps

Flood management is at a crossroads in California. Flood management agencies need to move away from fragmented flood management planning and implementation efforts, unreliable funding, and narrowly focused projects, toward an integrated approach to flood management. An IWM approach provides improved public safety, supports ecosystem enhancement, helps promote broad public and stakeholder support, and requires sufficient and stable funding to help manage flood risk.

This report provides a statewide inventory of flood system improvement needs and an estimate of the level of investment needed to provide an adequate level of flood management for California citizens. Additionally, engineering assessments and planning investigations conducted over the past several years provide a vast amount of information, knowledge, and understanding of the flood management system in California. The release of this report marks the end of Phase 1 of the Statewide Flood Management Planning Program, but the difficult work—the implementation of the seven recommendations and their associated actions—is still ahead. California's flood future depends on elected officials, stakeholders, and agencies at every level of government working together to improve public safety, foster environmental stewardship, and support economic stability.

Phase 2 of the Statewide Flood Management Planning Program will include:

- More detailed flood risk assessments
- Public education and policymaker awareness campaigns on flood risk
- Exercises and grant programs to bolster emergency preparedness, response, and recovery activities
- Greater involvement of land use planners and decision makers in flood management activities
- Greater inclusion of flood management agencies and stakeholders in existing IRWM groups and planning efforts
- Greater alignment on priorities and objectives, governance, and regulation of flood management activities
- Advancing flood management through an IWM approach
- Formulation of funding strategies to establish sufficient and stable funding for flood management activities

Sutter Buttes Mountain Range in North-Central California

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The complete report, *California's Flood Future: Recommendations for Managing the State's Flood Risk*, including technical attachments and other supporting information is available for review at:

http://www.water.ca.gov/SFMP