FloodSAFE CALIFORNIA

Technical Analyses

Supporting Development of the 2012 Central Valley Flood Protection Plan

June 2011

PUBLIC SAFETY ENVIRONMENTAL STEWARDSHIP ECONOMIC STABILITY

Workshop Goal

Inform CVFPP Work Group members, and other interested individuals and parties, of technical analyses supporting development of the Central Valley Flood Protection Plan

CVFPP Valleywide Forum, December 2010

2012 Central Valley Flood Protection Plan

The 2012 CVFPP will outline the State's Systemwide Investment Approach for long-term flood management improvements in the Central Valley

- System analysis
- Prioritized physical improvements that provide systemwide benefits
- Policy recommendations and guidance
- Implementation

City of Sacramento, Pocket Area

Workshop Agenda

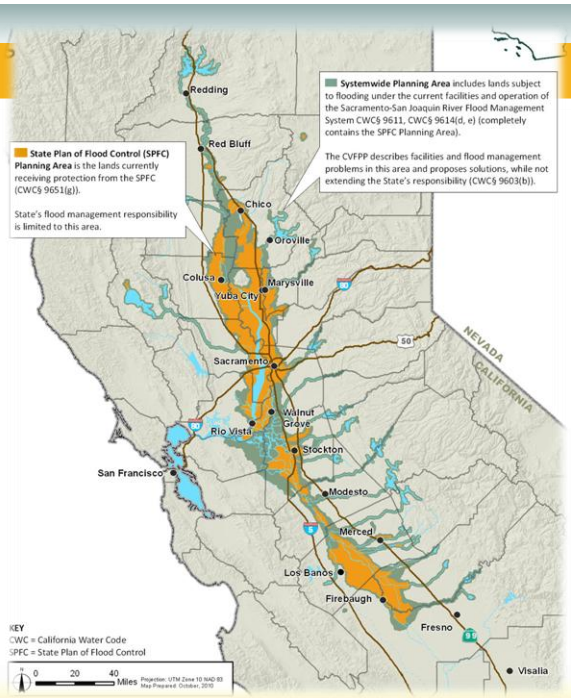
- Plan Formulation Overview
- Technical Evaluation Methods
- Achieve SPFC Design Capacity Approach
- Protect High Risk Communities Approach
- Enhance Flood System Capacity Approach
- Approach Comparison
- State Systemwide Investment Approach
- Next Steps for CVFPP Development

Handout 1

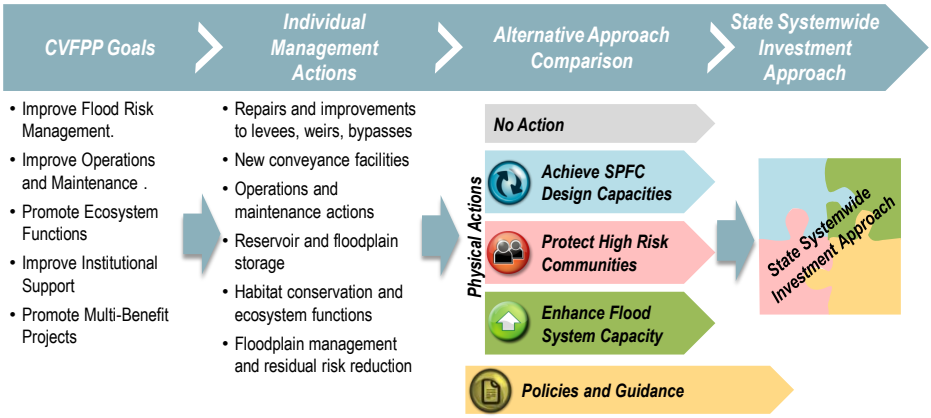
Plan Formulation Overview

Planning Areas

- State Plan of Flood Control Planning Area
- Systemwide Planning Area



Formulating Systemwide Approaches



Alternative Approaches

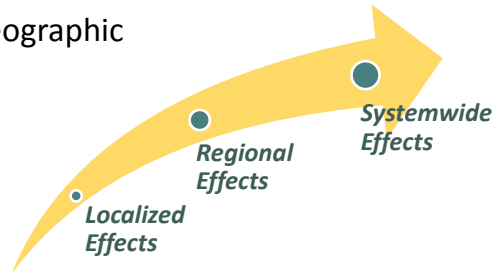
Formulated to help identify the advantages and disadvantages of different combinations of management actions, and inform development of the State Systemwide Investment Approach

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

Handout 2

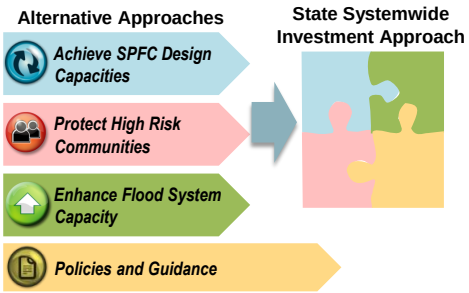
Purpose of Approach Analysis

- Designed the systemwide analysis approach to consider the full range of management actions and project types identified in Phases 1 and 2, at a reconnaissance level
  - Effects of potential actions and combinations of actions
  - Opportunities to achieve multiple benefits
  - Magnitude and geographic scale of potential benefits/effects



Use of Approach Analysis Results

- Findings will be used to build the State Systemwide Investment Approach
- Vehicles for advancing these ideas further, as we move toward the 2017 Update
  - FloodSAFE and other DWR Projects/Programs
  - USACE/DWR/CVFPB Central Valley Integrated Flood Management Study

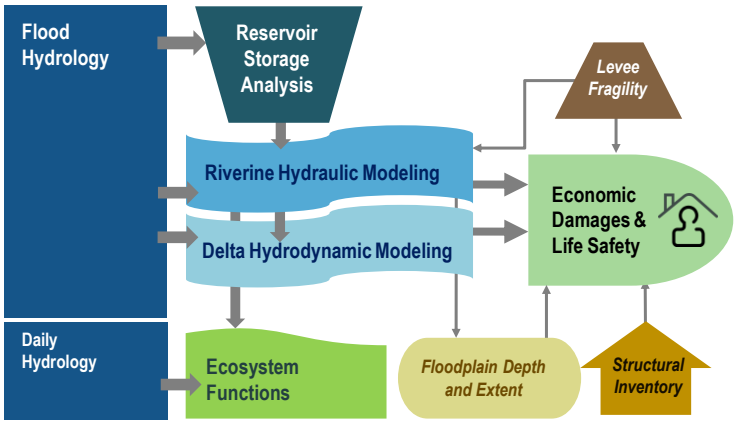


Technical Evaluation Methods

Technical Efforts Supporting 2012 CVFPP

- Hydrology
- Reservoir Operations
- Channel Evaluations (hydraulics)
- System Levee Performance
- Floodplain Hydraulics
- Economic Damages
- Ecosystem Functions
- Life Safety and other Benefits
- Preliminary Designs and Costs

Systemwide Analysis Tools & Data



Handout 3

Flood Hydrology

Synthetic Flood Hydrology

- Synthetic hydrology originally developed by USACE and DWR for the Sacramento – San Joaquin River Basins Comprehensive Study in the late 1990s
  - 5 storm centerings per basin
  - 6 frequency events
- New, updated hydrology for use in future studies and plan updates is currently being developed by Central Valley Hydrology Study

6 flood events were simulated with the following chances of occurring in any given year:

- **10%** (10-year)
- **4%** (25-year)
- **2%** (50-year)
- **1%** (100-year)
- **0.5%** (200-year)
- **0.2%** (500-year)

Reservoir Storage

Reservoir Storage Analysis

- Uses HEC-5 reservoir operation models developed originally for the Comprehensive Study, updated to reflect current conditions
  - Over 70 reservoirs simulated
  - Uses flood hydrology as input
  - Generates reservoir releases as input to hydraulic models
- Allows simulation of different operational scenarios
  - Increasing / decreasing flood storage allocation and objective releases, changing operational rule curves, etc.

Levee Fragility

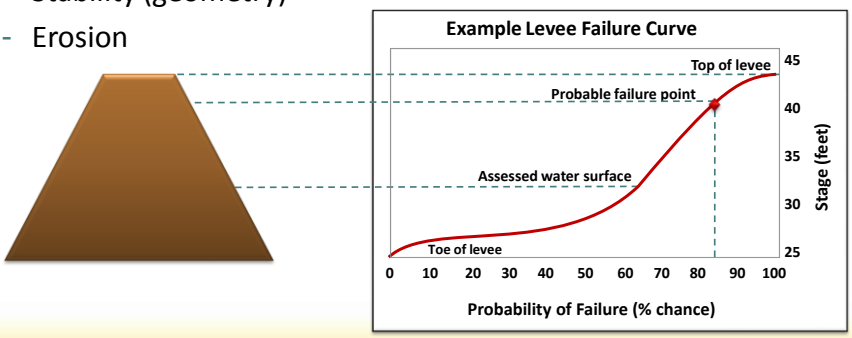
System Levee Performance

- Describes the condition of levees and potential likelihood of water leaving channels prior to overtopping
- Developed using information being collected by FloodSAFE Urban and Non-Urban Levee Elevation Programs
- Defines system performance and levee failure potential in both hydraulic models and economic damage analyses

Levee Fragility

Levee Fragility Curves

- Represents probability of levee failure based stage
- Composite of several possible failure modes
  - Through seepage
  - Under seepage
  - Stability (geometry)
  - Erosion



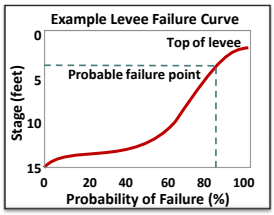
Riverine

Riverine Hydraulic Analyses

- Simulates flood flows and stages in river channels and waterways, including weirs and bypasses
- Uses UNET unsteady flow models developed originally for Comprehensive Study, updated to current conditions
  - 1,400 miles of channels (5,000 cross-sections) simulated
- New hydraulic models under development by Central Valley Floodplain Evaluation and Delineation Program for use in future studies and plan updates

Riverine

UNET Model Structure



Upstream storm event

Upstream storm event

Reservoir release

Inputs

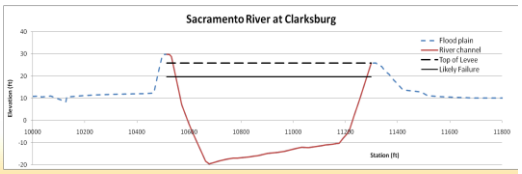
- Levee failure scenario
- Weir operations
- River geometry and roughness

Outputs

- Flow rates
- Water surface stages
- Levee breach location
- Overbank flow
- Return flow

Delta Hydraulic Model

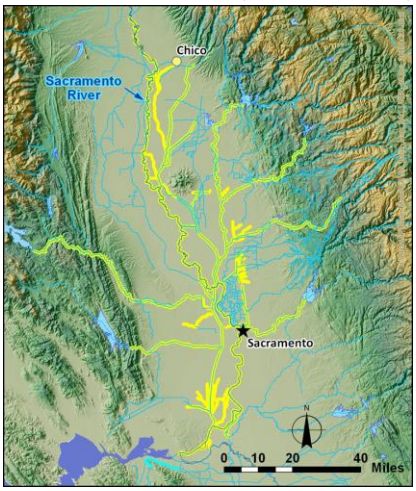
Tailwater stage



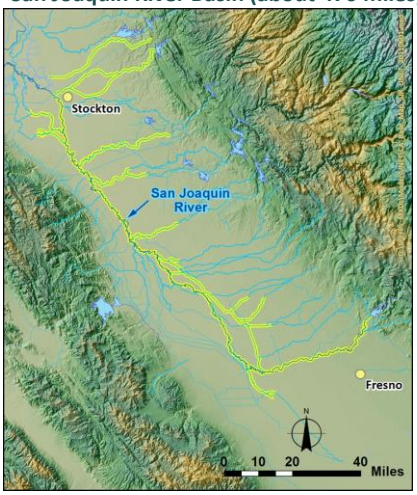
Riverine

UNET Model Coverage

Sacramento River Basin (about 920 miles)



San Joaquin River Basin (about 470 miles)



Delta

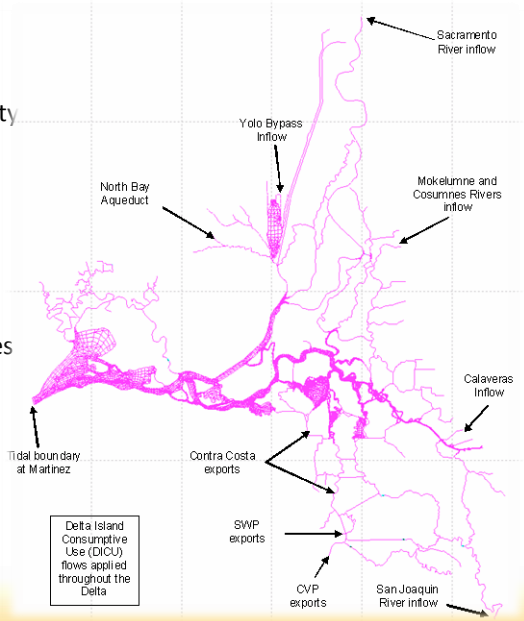
Delta Hydrodynamic Analyses

- Simulates flows and stages in the Sacramento-San Joaquin Delta estuary
- Uses two-dimensional RMA Delta simulation model
- Evaluates potential effects of upstream actions on the Delta
- Output from UNET used as upstream boundary conditions

Delta

RMA Delta Model

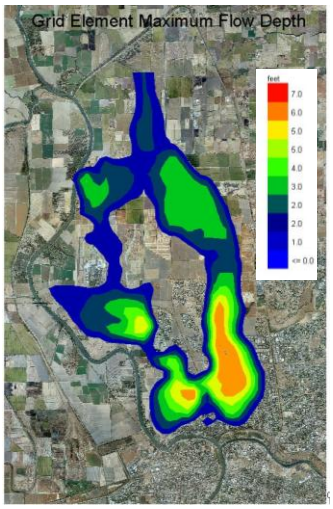
- Finite Element Model
  - 2-dimensional dynamic velocity and water surface elevation
- Key Inputs
  - Output from riverine UNET analysis
  - Tidal stage at Martinez
  - Operation of control structures
- Outputs
  - Flow rates
  - Water surface stages



Floodplain Depth and Extent

Floodplain Hydraulics

- Uses FLO-2D grid-element model to represent floodplain topography and roughness
  - Simulate flow that travels out of channel and across floodplain
  - Uses overbank flow from UNET
  - Estimates water depth in the floodplain
- 2012 CVFPP is using FLO-2D results from the Comprehensive Study
- 2017 CVFPP will use new floodplain models to generate updated floodplains

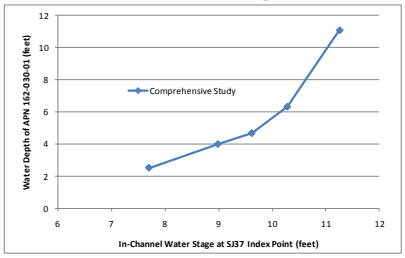


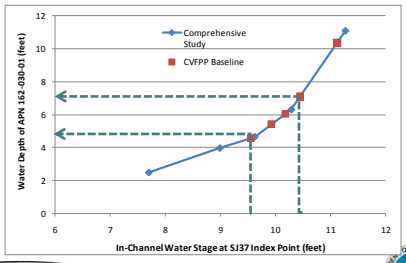
Floodplain Depth and Extent

Floodplain Depth Derivation

- Interior (floodplain) – exterior (in-channel) flood stage relationship from Comprehensive Study
  - Based on Comprehensive Study UNET index point stage outputs and FLO-2D depth grids for each parcel
  - Relationship remains independent of hydrologic and levee fragility conditions
- CVFPP new exterior stage for each flood event
- Derive CVFPP new interior stages using the original interior-exterior stage curve

Interior-exterior stage curve





Daily Hydrology → Ecosystem Functions

Ecosystem Functions Analysis

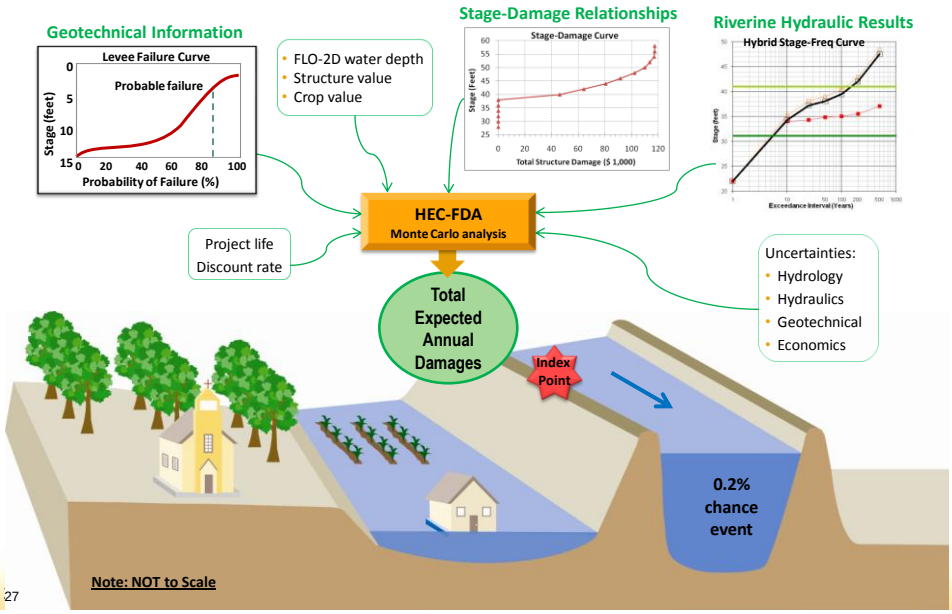
- Help identify opportunities to improve habitat quantity, quality, and connectivity within system
- Considers the frequency and depth of flows in floodplains, and the ecosystem processes and habitats these conditions might support
  - Uses topographic information and historically-based daily hydrology from CALSIM
- Supports integration of conservation elements
- HEC-EFM under development for use in future studies and plan updates

$$

Economic Damages

- Estimates potential monetary damages to property and agriculture from floods
- Uses HEC-FDA flood damage analysis model, developed originally for the Comprehensive Study but with substantial updates
  - Extended model coverage
  - New structural inventory
  - New crop inventory
  - Updated fragility curves
- Probabilistic analysis of flood frequency, extent, depth, and damages

$$ HEC-FDA Key Inputs

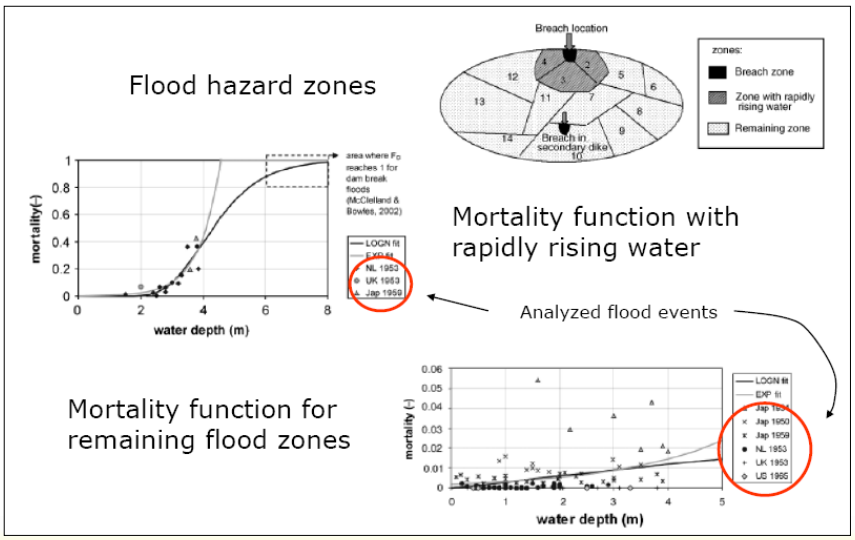


Life Safety

- Assesses the exposure of populations to flood hazards and resulting life safety implications
- Analyzes a full range of flood frequencies using HEC-FDA considering
  - Population and occupancy data
  - Effectiveness of evacuation and warning systems
  - Empirical data on life safety derived from previous flood events
- Analyses for future plan updates may consider models that more directly address evacuation and other community characteristics

Life Safety

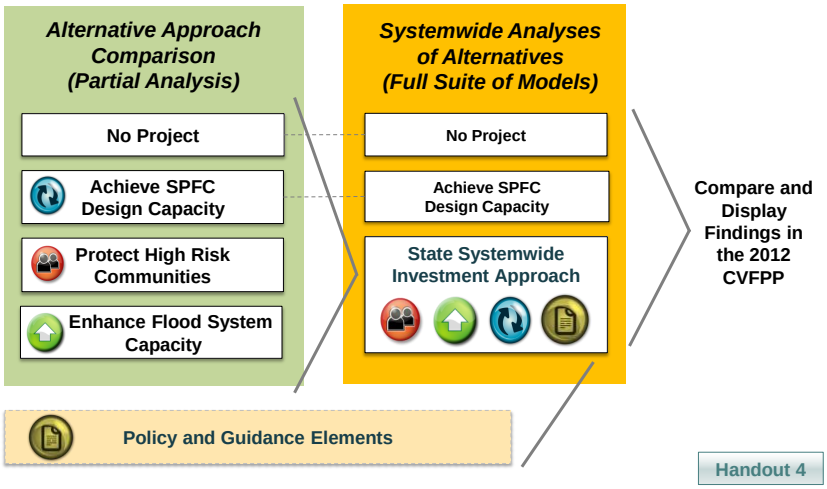
Jonkman Function



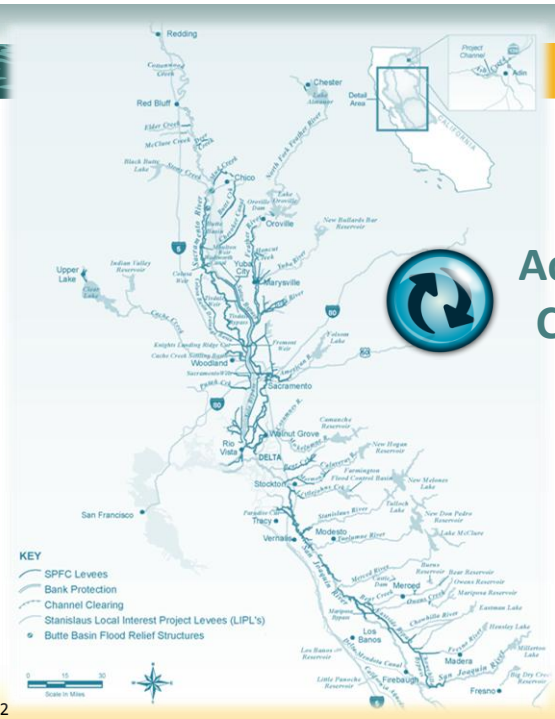
Key Outputs of Systemwide Analyses

System Performance	Stage, Flow, Volume
Economic Damages	Expected Annual Damages
Life Safety	Life Safety Index
Environmental Benefits	Restoration Opportunities
Costs	Capital, O&M

Application of Analysis Tools & Data



Handout 4



Achieve SPFC Design Capacity Approach

Approach Overview

CWC 9614 (g) states that the CVFPP shall include an evaluation of the structural improvements and repairs necessary to bring each State Plan of Flood Control facility to within its design standard

- A significant initial investment would be made to correct identified hazards and reconstruct (but not enhance) SPFC facilities
- Primarily includes in-place levee reconstruction actions to improve the reliability of the system in passing design flows

SPFC Facilities Evaluation

- Uses information under development for the Flood Control System Status Report (FCSSR) to identify facilities that do not meet current standards for
  - Geometry (height, width, slope, etc) and freeboard
  - Stability and seepage design criteria
  - Capacity to convey design flows
- A public review draft of the FCSSR is scheduled for later this summer

Addressing Facility Conditions

- This approach would involve action along
  - About 180 miles of urban SPFC levees
  - About 1,200 miles of non-urban SPFC levees
  - 200 miles of appurtenant non-project levees
- Remedial actions to address through seepage, under-seepage, stability, waterside erosion, freeboard and geometry are applied to:
  - Non-Urban levees with high or medium hazard level
  - Urban levees that does not meet criteria or marginally meet criteria

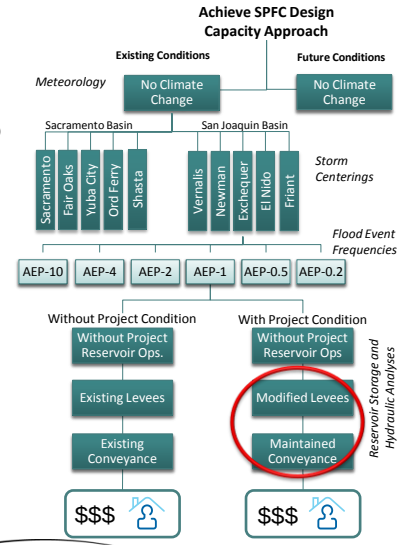
Example of Remedial Actions

Levee repair work on Sacramento River, RM 49.9

Construction of cut-off wall on Natmoas Cross Canal South Levee

Data and Tools Used

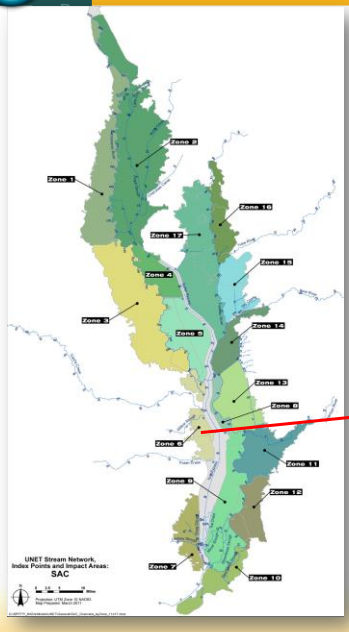
- Management actions applied:
  - No change to reservoir storage & operations
  - In-place fix and/or levee raise to address identified levee conditions
  - Bypass and weir rehab to achieve design conveyance
- Full suite of system analyses applied:
  - Hydrology & Hydraulics
  - Economics & Life Safety
  - Engineering Design & Cost



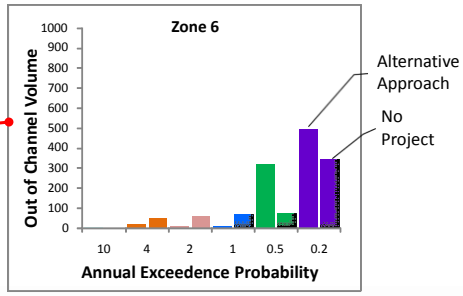
Initial Assessment – System Performance

- Levels of flood protection associated with SPFC design flow capacities vary throughout the system
- Improvements to achieve design capacities would not necessarily provide the levels of protection people desire
  - Does not provide <u>all</u> urban areas with protection from a 0.5% annual chance (200-year) event
  - Provides increased level of protection to some small communities and rural areas, but varies regionally
- Improving the reliability of upstream levees may create system impacts during certain frequency floods

Example Model Output – System Performance



- Passing design flows would reduce the frequency and magnitude of flooding in some locations for some events, but effects vary regionally



Initial Assessment – Cost

- Initial cost of levee improvements ($billions)

		Total
Sacramento River Basin	Preliminary results subject to change	$9- $11
San Joaquin River Basin		$3 - $4
Total		**$12 - $15**

- These initial costs include construction of in-place levee reconstruction, rights of way, and mitigation for construction-related impacts
- Initial decrease in O&M costs due to investments in SPFC reconstruction, but long-term O&M costs would remain high

Other Initial Considerations

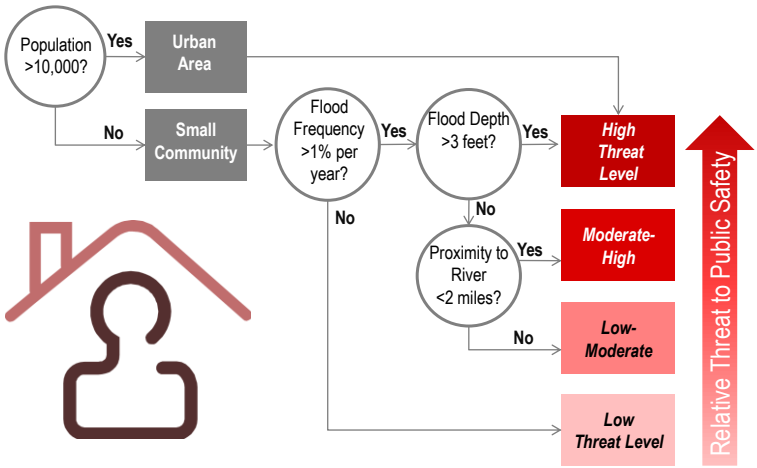
- Fixing levees in-place provides limited opportunities to
  - Improve ecosystem functions
  - Integrate other benefits (water supply, recreation)
  - Address erosion and other chronic O&M challenges related to conflicts with natural geomorphic processes
- Would not improve system resiliency or ability to adapt to future changes

Protect High Risk Communities Approach

Approach Overview

- Focuses on the threats flooding poses to life safety
- Investments would be prioritized to address identified facility hazards and/or increase the level of flood protection in
  - Dense urban areas
  - Small communities subject to frequent, deep and/or rapid flooding
- Other SPFC facilities would continue to be operated, maintained and repaired as under existing conditions

Methodology



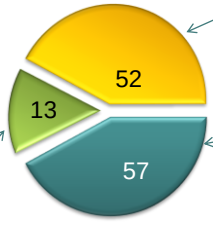
Identification of Communities

- List of communities within the Systemwide Planning Area is based on:
  - California Department of Finance
  - Census Designated Places (2000 Census)
  - California List of Places (U.S. Geological Survey Topo Quad)
- 2007 Population estimates is based on:
  - 2000 Census projections
  - California Department of Finance estimates

Characterization of Flood Threats

- Flood Frequency (greater or less than 1% AEP):
  - Comprehensive Study (USACE, 2002).
  - FEMA 100-year floodplain maps information
- Flood Depth (greater or less than 3 feet):
  - Levee Flood Protection Zones (LFPZ) (DWR, 2008)
  - Comprehensive Study 200-year floodplain depths (USACE, 2002)
- Proximity to the nearest river (greater or less than 2 miles of SPFC levee or other major stream)

Initial Assessment – Community Threat Level



Urban Areas
(High Threat Level)

Small Communities Contiguous with Urban Areas
(High Threat Level)

Preliminary results subject to change

Small Communities

Threat Level	Receive Protection from SPFC	Outside SPFC
High	9	1
Moderate-High	11	9
Low-Moderate	4	2
Low	6	15
Total	**30**	**27**

Handout 5

Initial Assessment - System Performance

- Urban areas achieve protection from a 0.5% annual-chance flood
  - SPFC levee improvements and/or raise
- Small communities achieve protection from a 1% annual-chance flood
  - SPFC levee improvements and/or raise
  - Ring levees and/or new levees
- No change in level of flood protection in other areas of the system

Initial Assessment – Cost

- Initial cost of improvements ($billions):

		Total
Sacramento River Basin	Preliminary results subject to change	
San Joaquin River Basin		
Total		**$2.0 – $TBD**

- Cost information include:
  - ULE/NULE Programs
  - EIP and Subvention Programs
- Long-term O&M costs would remain high

Other Initial Considerations

- Focusing only on populations at risk provides limited opportunities to
  - Improve ecosystem functions
  - Integrate other benefits (water supply, recreation)
  - Address erosion and other chronic O&M challenges related to conflicts with natural geomorphic processes
- Would not improve system resiliency or ability to adapt to future changes

LUNCH BREAK

Enhance Flood System Capacity Approach

Approach Overview

- Seeks opportunities to achieve multiple benefits through enhancing flood system storage and conveyance capacity
- Would involve modification to the form and function of the flood management system
  - Conveyance improvements to channels, bypasses, and control structures
  - Increased storage in reservoirs and floodplains
- Fully integrates environmental restoration and water supply benefits

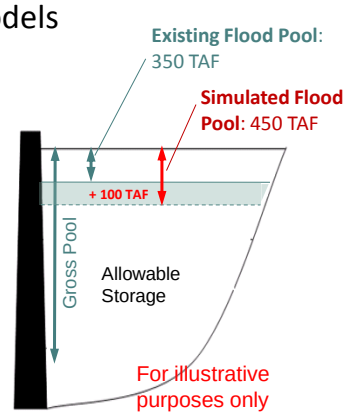
Approach Elements

- This approach include wide array of management actions:

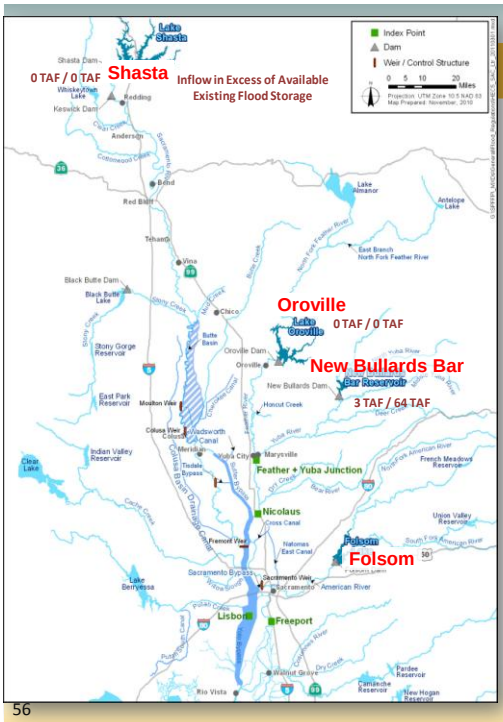
Management Actions	Sacramento River Basin	San Joaquin River Basin
Reservoir storage	■	■
Floodplain storage	■	■
Floodway expansion	■	■
Weir and bypass modification	■	■
Ecosystem restoration opportunities	■	■
Groundwater recharge opportunities	■	■

Reservoir Analysis

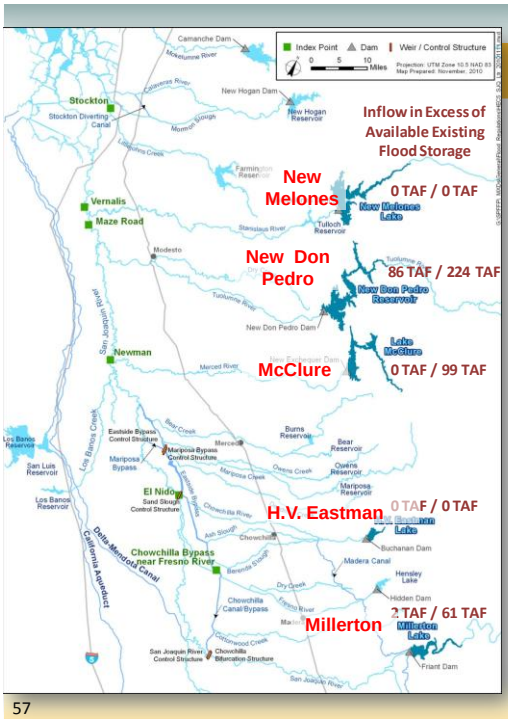
- Used HEC-5 reservoir simulation models
- Identify which reservoirs are most effective in lowering downstream peak flow
- Formulated potential scenarios by
  - Increasing flood storage allocation
  - Changing objective releases
- Explored potential flood management benefits, as well as water supply reliability effects



Sacramento River Basin



- Evaluated 4 multi-purpose reservoirs
  - Shasta, Oroville, New Bullards Bar, and Folsom
  - Considered 1% and 0.5% chance events (100- and 200-year return periods) for Sacramento centered storm
- Results identified opportunities to reduce flood peaks on the Feather River through coordinated operations of Oroville and New Bullards Bar



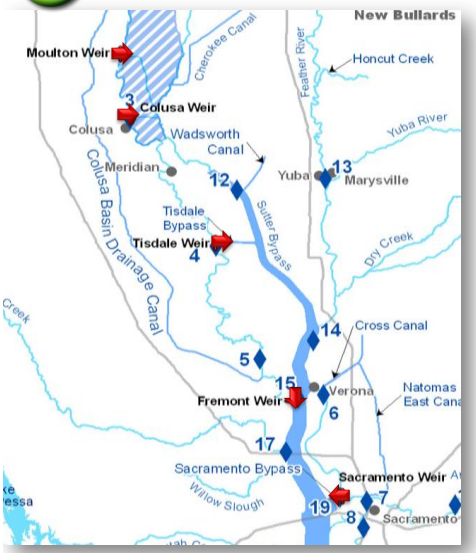
San Joaquin River Basin

- Evaluated 5 reservoirs
  - New Melones, New Don Pedro, Lake McClure, H.V Eastman, and Millerton
  - Considered 2% and 1% chance events (50- and 100-year return periods) for Vernalis centered storm
- Results identified additional flood space needed at New Don Pedro, McClure, and Millerton to reduce flood peaks

Conveyance & Floodplain Storage Analyses

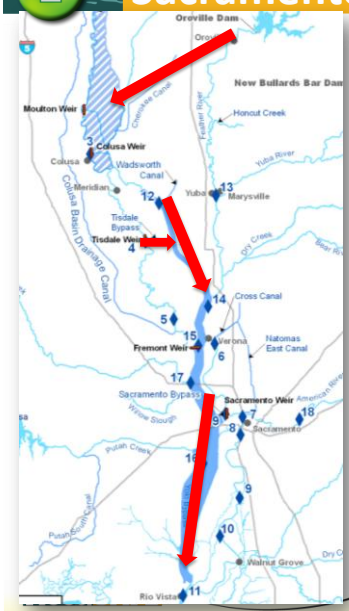
- Used UNET and RMA Delta models for hydraulic analyses
- Formulated potential scenarios that considered
  - Weir modification
  - Bypass expansion
  - Floodway expansion (setback levees)
  - Floodplain storage
- Evaluated magnitude and extent of flood peak reduction
  - Localized
  - Regional
  - Systemwide

Sacramento – Weir Modification



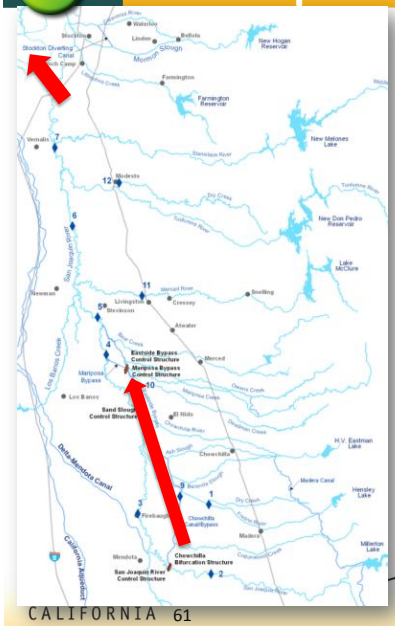
- Considered Moulton, Colusa, Tisdale, and Fremont weirs
- Modifications included weir lowering and widening
- Weir lowering would generally provide localized flood peak reductions
- Weir widening with bypass expansion would provide regional flood peak reduction

Sacramento – Bypass Expansion



- Considered Tisdale, Sutter, and Yolo bypasses
- Bypass modifications included
  - Bypass widening
  - Increasing bypass efficiency *(via sediment and vegetation management)*
  - New Feather River to Butte Basin bypass
- Bypass expansion (including weir modifications) would provide regional flood peak reduction
- May require flood easements to address downstream hydraulic impacts

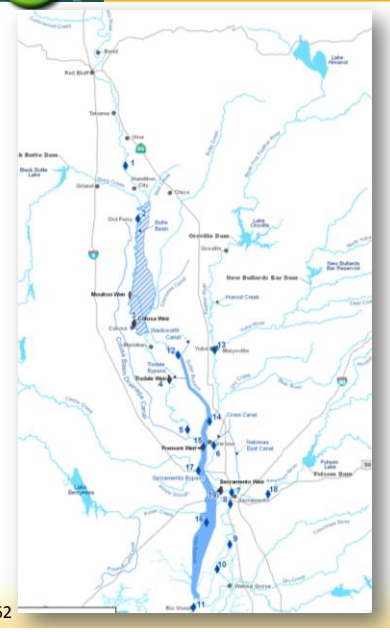
San Joaquin – Bypass Expansion



- Bypass options considered included
  - Expansion of Paradise Cut
  - Restoring design capacity to Chowchilla, Eastside, and Mariposa bypasses
- Bypass expansion would provide regional flood peak reduction
- May require flood easements to address downstream hydraulic impacts

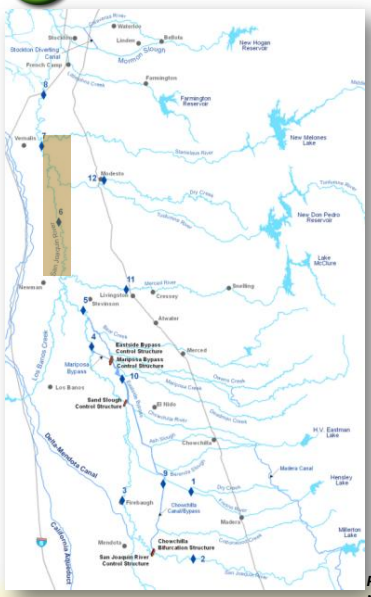
ENVIRONMENTAL STEWARDSHIP ECONOMIC STABILITY

Sacramento – Floodway Expansion

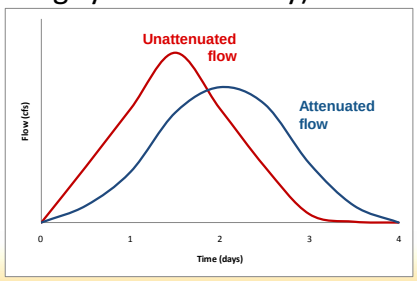


- Setback levees considered along the bypass system to increase capacity
- Setback levees along the mainstem Sacramento River and major tributaries considered in short reaches to address:
  - Chronic O&M sites
  - Ecosystem restoration opportunities
- Floodway expansion opportunities limited by:
  - Perched river system
  - Infrastructure and existing land uses

San Joaquin – Floodway Expansion

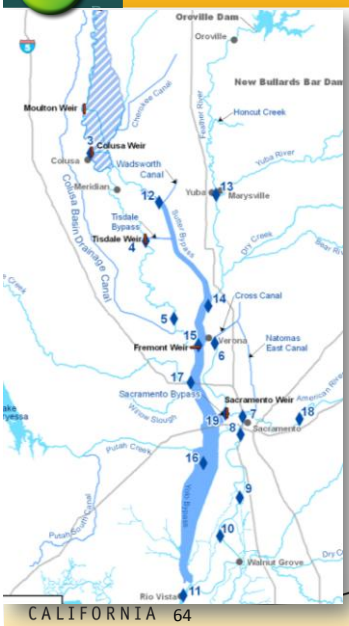


- Considered setback levees between:
  - Merced River and Tuolumne
  - Tuolumne and Stanislaus
- Floodway expansion would provide local flood peak reduction
- Flood attenuation is required (adding system flexibility)



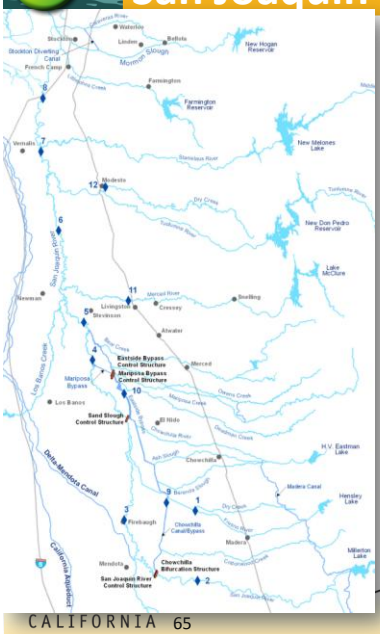
For illustrative purposes only

Sacramento - Floodplain Storage



- Considered floodplain storage opportunities in upper and lower Sacramento Regions
  - Adjacent to Sutter Bypass
  - Adjacent to Yolo Bypass
- Would provide local and regional flood peak reduction benefits
- Constraints
  - Compatibility with existing land uses
  - Effects on infrastructure

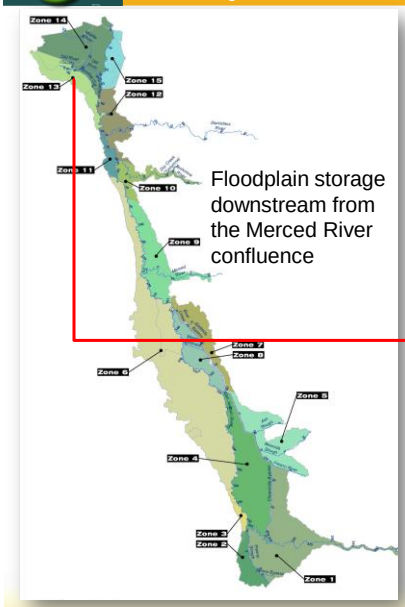
San Joaquin – Floodplain Storage



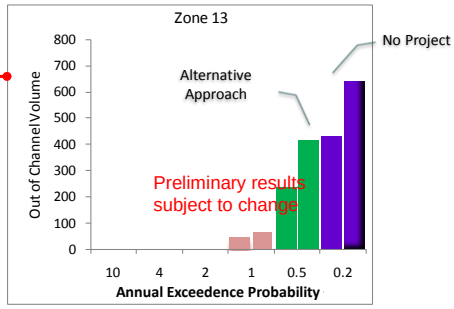
- Considered floodplain storage opportunities in upper and lower San Joaquin Regions
  - Fresno Slough
  - Merced to Tuolumne
  - Tuolumne to Stanislaus
  - Downstream from Stanislaus
  - Proximity of Paradise Cut
- Would provide local and regional flood peak reduction benefits
- Constraints
  - Compatibility with existing land uses
  - Floodwater storage capacity

ENVIRONMENTAL STEWARDSHIP ECONOMIC STABILITY

Example Model Output - Floodplain Storage



- Floodplain storage helps attenuate flood peaks
- Some reduction in flood stages and overbank flows downstream can be observed during some flood events

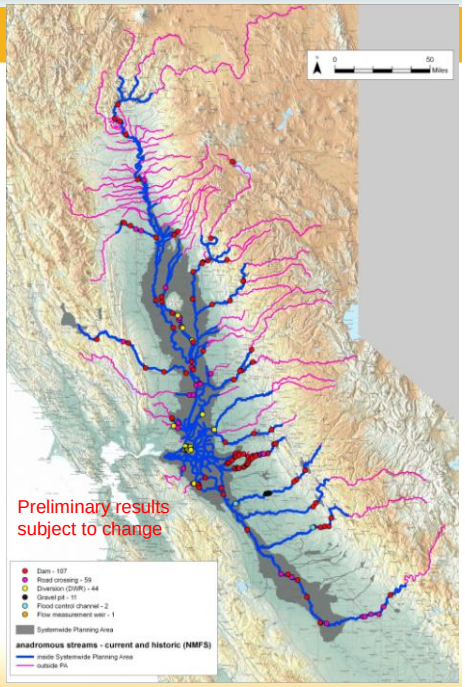


Restoration Opportunities Analysis

- Technical work in-progress
  - Fish Passage Barriers Report
  - Med-scale vegetation/land cover mapping
  - Biological Status and Trends Report
  - Ecological floodplain inundation potential & restoration opportunities evaluation
  - Regional Advance Mitigation Planning (RAMP)

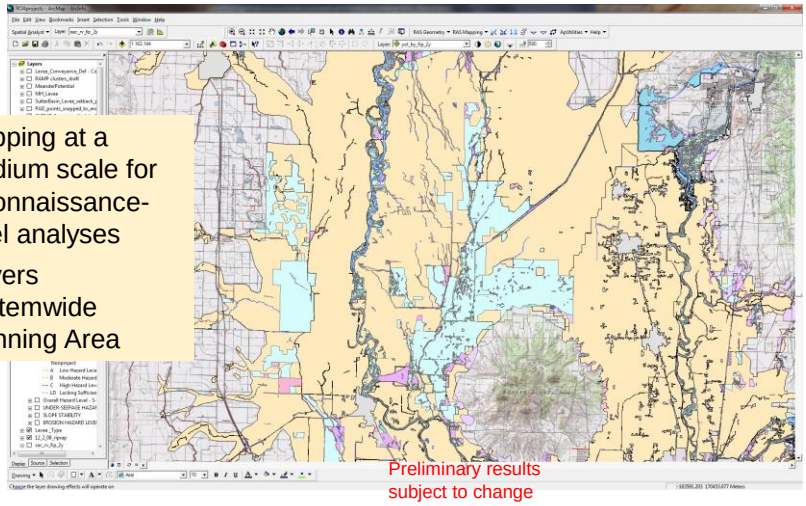
Fish Passage

- Identified known and potential fish passage barriers within the Central Valley flood management system
  - Passage assessment database
  - Expert knowledge



Medium-Scale Vegetation & Land Cover Mapping

- Mapping at a medium scale for reconnaissance-level analyses
- Covers Systemwide Planning Area

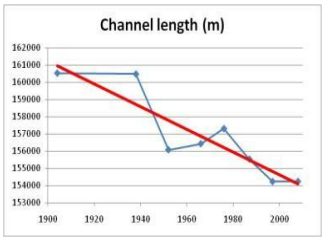


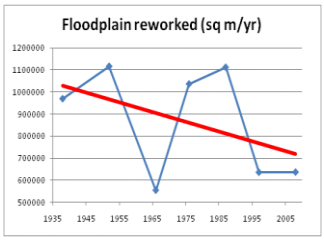
Preliminary results subject to change

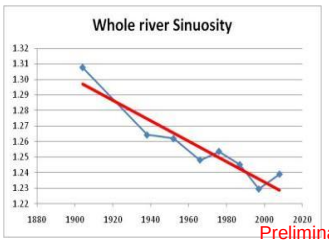
Biological Status and Trends Report

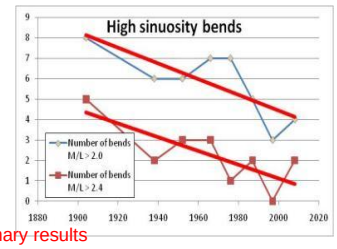
Example Metric:

- Sacramento River channel length and sinuosity





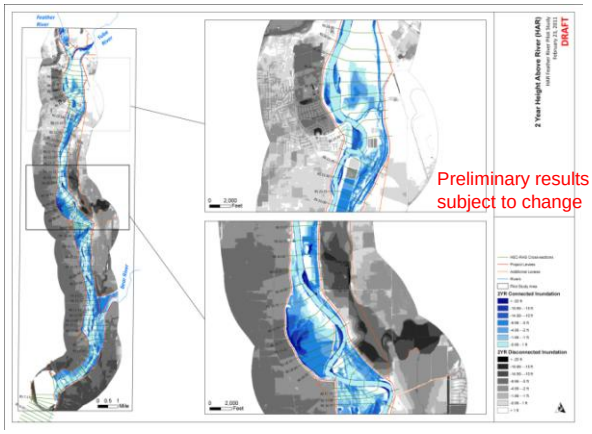




Preliminary results subject to change

Ecological Floodplain Inundation Potential

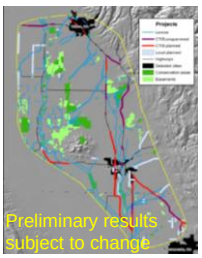
- Digital terrain topography (LiDAR)
- 2- and 10-year flow recurrence
- Salmon FAF Flows
- Estimates depth of inundation (inside and outside levees)



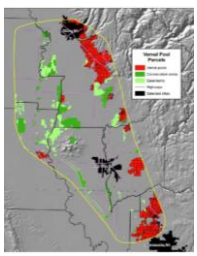
Regional Advance Mitigation Planning

Modeling Analyses - MARXAN

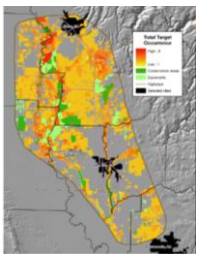
- Sacramento Valley study area
- Suitability analyses



Map existing conservation land and planned infrastructure projects



Map resources that may need mitigation due to potential impacts



Assess suitability of existing properties to meet mitigation needs

Groundwater Recharge Opportunities

- Used published data and studies to identify potential opportunities for enhanced groundwater recharge in conjunction with flood management activities to
  - Increase flood management flexibility
  - Increase water supply reliability
- Three modes of groundwater recharge were considered
  - Recharge projects associated with reservoir operations
  - Groundwater banking projects associated with capturing unappropriated flood flows
  - Direct recharge associated with activities in the floodplain (e.g., transitory storage)

Handout 6

Conjunctive Water Use Opportunities

- Promote integrated water management strategy:
  - Increase water supply reliability and flexibility
  - Mitigation for potential increases in flood space allocations
- Scale of recharge opportunities includes the following:
  - Up to 400 TAF in the Sacramento Basin
  - Up to 340 TAF in the San Joaquin Basin
- DWR's System Reoperation Study will further evaluate these potential opportunities to improve flood management

Recharge using Flood Releases

- Flood flows can be directly diverted from rivers to provide water supply benefits, including in-lieu and direct groundwater recharge
- Recharge opportunities are limited by
  - Hydrogeologic suitability (recharge potential)
  - Delivery infrastructure
- Opportunities are limited in the Sacramento River Basin because the groundwater basin is relatively full
- Direct recharge is more applicable in the San Joaquin valley because overdraft conditions exist

Direct Recharge of Floodwaters

- Direct recharge opportunities can be integrated with transitory storage projects by allowing floodwaters to infiltrate floodplains
- Direct recharge (via transitory storage) opportunities are limited both in the Sacramento and San Joaquin systems by
  - Inundation frequency and duration
  - Hydrogeologic properties that determine infiltration rates and volumes (soil permeability and depth to groundwater)

Initial Assessment – Cost

- Initial cost of levee improvements (billions)

		Total
Sacramento River Basin	Under development	
San Joaquin River Basin		
Total		**$TBD**

Approach Comparison

Contributions to CVFPP Goals

	Achieve SPFC Design Capacity	Protect High Risk Communities	Enhance Flood System Capacity
Contributions to Primary Goal - Improve Flood Risk Management			
Level of Flood Protection	Varies throughout system	High in urban areas and small communities, varies elsewhere	Overall higher protection, but varies throughout system
Life Safety	Some Improvement	Highest Improvement	Improvement Varies
Economic Damages	Reduction in Rural Area Damages	Reduction in Urban and Small Community Damages	Reduction in Urban and Rural Area Damages

Handout 7

Contributions to CVFPP Goals (cont)

	Achieve SPFC Design Capacity	Protect High Risk Communities	Enhance Flood System Capacity
Contributions to Supporting Goals			
Improve Operations & Maintenance	Initial decrease in O&M costs	No change	Decrease in long-term costs
Promote Ecosystem Functions	Limited opportunities	Some opportunities	Substantial opportunities
Improve Institutional Support	Not Analyzed		
Promote Multi-Benefit Projects	Very limited opportunities	Limited opportunities	More Opportunities

Systemwide Efficiency and Sustainability

	Achieve SPFC Design Capacity	Protect High Risk Communities	Enhance Flood System Capacity
Efficiency			
Capital Cost	Very High	High	Very High
Annual Costs	High	High	Low-Moderate
Estimated Timeframe for Implementation	15-20 years	10-15 years	20+ years
Ability to Meet Legislation Objectives	Partially meets	Partially meets	Mostly meets
Overall Sustainability			
Financial, Environmental, Social	Low	Low	Medium

State Systemwide Investment Approach (SSIA)

SSIA Overview

The SSIA will represent the State's strategy for long-term flood management improvements in the Central Valley

- Includes components of the three Alternative Approaches
- Achieves CVFPP goals from a systemwide perspective
- Integrates conservation elements
- Focuses on developing an economically, socially, and environmentally sustainable flood management system

Elements of the SSIA

- Policy and implementation elements to support long-term Plan implementation
- Physical improvements and modifications to the flood management system
- Residual risk management and sustainable O&M
- Integrated conservation elements to improve ecosystem functions within the flood management system

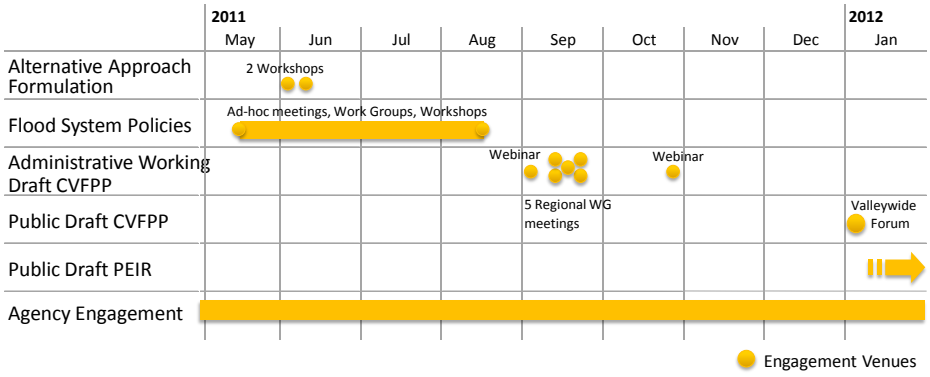
Next Steps for CVFPP Development

Near-Term Activities

- Continue technical analyses and formulation of SSIA
- Continue policy development
- Schedule and prepare webinars on Administrative Working Draft CVFPP
- Schedule and prepare for Regional Work Group meetings to discuss Administrative Draft CVFPP

Upper Sacramento Regional Work Group Meeting

Communication and Engagement Schedule



Contact Information

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