**VOLUME 3** - RESOURCE MANAGEMENT STRATEGIES

**CHAPTER 4**

# Flood Management

***Sacramento, CA.*** The Pocket-Greenhaven community is bordered by I-5 and a semi-circular bend in the Sacramento River on the south, west, and north, and is crossed by a large canal system. Levees protecting houses in "The Pocket" have been determined by the Sacramento Area Flood Control Agency to be in need of major repairs, to retain their 100-year flood protection.

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# Chapter 4. Flood Management

This resource management strategy (RMS) for flood management is unique to the other strategies in the *California Water Plan Update 2013* (Update 2013) in that it contains multiple approaches within a single RMS. Flood management is complex and still relatively new to the California Water Plan (CWP). For Update 2013, this flood management RMS provides local and regional water managers a broader perspective of the flood management tools that are available and their interrelationships within one chapter. In future CWP updates and as flood management becomes more integrated into the CWP, more than one RMS for flood management could be developed.

This flood management RMS has been subdivided into four approaches:

- Nonstructural.
- Restoration of natural floodplain functions.
- Structural.
- Flood emergency management.

The following sections will discuss flood management in general terms followed by specific subsections related to the four approaches identified above, as necessary.

## Flood Management in California

Floods are naturally occurring phenomena in California. Flooding varies according to the diversity of landscape features, climate, and human manipulation of the landscape. Flooding occurs in all regions of California at different times of the year and in different forms. Examples range from tsunamis in coastal areas to alluvial fan flooding at the base of hillsides, and from fast-moving flash floods in desert regions to slow-rise deep flooding in valleys. Flooding can have positive natural impacts, such as keeping erosion and sedimentation in natural equilibrium, replenishing soils, recharging groundwater, filtering impurities, and supporting a variety of riverine and coastal floodplain habitats for some of California's most sensitive species. However, when floods occur where people live and work, they can result in tragic losses of lives and can have devastating economic impacts by damaging critical infrastructure and vital public facilities, taking valuable agricultural land out of production, and endangering California's water supply system.

In traditional flood management, the overarching purpose is to separate flood waters from people and property that could be harmed. In contrast, integrated water management (IWM) seeks a balance between exposure of people and property to flooding, the quality and functioning of ecosystems, the reliability of water supply and water quality, and economic stability that includes both economic and cultural considerations. This shift changes the focus of flood management from a local to a systemwide context.

One benefit of using IWM is that it encourages a systemwide perspective to solving flood issues as well as an increased understanding of the cause and effect of different management actions. This moves solutions beyond just reducing flood risk resulting from the 100-year flood event to meet the Federal Emergency Management Agency (FEMA) National Flood Insurance Program (NFIP) requirements to an integrated approach that reduces flood risk and also supports other

objectives over a multitude of flood events. Box 4-1 provides the definition of a 500-year and a 100-year flood event.

Traditional flood management approaches inadvertently allowed development in floodplains, putting people and property at risk. An IWM approach is balanced and leads to addressing a wide variety of needs. For example, projects are assessed based on the following attributes:

- Potential velocities and timing of flood flows as well as resources that could be disturbed or damaged by those velocities and timings.
- Depth and duration of floodwaters both during the event and after the event.
- Ecosystem processes that could be either enhanced or diminished by projected flows.
- Stability of floodways including potential for scour, erosion, sediment transport, and deposition.
- Opportunities for community and private access and use of lands dedicated to the flood path.
- Alternative or combined uses of the lands that make up the flood path.
- Risks to the community should a flood occur, and recovery capabilities following a flood.
- Water supply implications from the flood management system and operating conditions before, during, and after flood events.

Flood management includes policies and practices related to educating the public, preparing for mitigating damages, responding to and recovering from flooding that creates risk for people and valued resources, as well as protecting the natural and beneficial functions of floodplains to the maximum extent practicable. Traditional approaches to flood management consisted of developing single-purpose flood infrastructure projects, like a dam or a levee, which has resulted in an extensive network of flood infrastructure around the state, including the following:

- More than 20,000 miles of levees.
- More than 1,500 dams.
- More than 1,000 debris basins.
- Many other facilities, including pump stations, monitoring facilities, bypasses, and weirs (California Department of Water Resources 2013).

While this infrastructure has reduced the chance of flooding and avoided damage to lives and property, it has altered and confined natural watercourses. These alterations lead to unintended consequences, such as loss of ecological function and redirection of flood risks upstream or downstream of projects. Additionally, these traditional approaches have encouraged urban and agricultural development within floodplains, which has placed people and property at risk of flooding, as well as degrading wildlife habitat. In 2007, legislation was passed in California to enhance statewide understanding of flooding and address flood-related issues. This legislation is summarized in more detail in Chapter 24, "Land Use Planning and Management," in this volume.

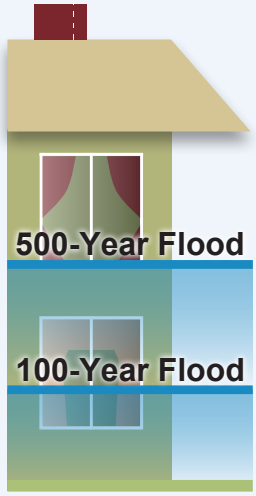
Even with its existing infrastructure, California is at significant risk due to flooding. Further development in flood-prone areas, population growth, and climate change will lead to an increased risk of flooding in the future for people and property. While flood infrastructure can reduce the intensity and frequency of flooding, it cannot completely eliminate the flood risk (i.e., residual flood risk will remain). *California's Flood Future Report: Recommendations for Managing the State's Flood Risk* (aka Flood Future Report) (California Department of Water

**Box 4-1 Definition of a 500-Year and 100-Year Flood Event**

**Two flood event levels are commonly used for insurance and planning purposes. These levels indicate a percentage of probability and severity. It does not mean a flood only happens every 100 or 500 years.**

- **500-Year Flood** is a shorthand expression for a flood that has a 1 in 500 probability of occurring in any given year. This may also be 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.

**Figure A. 500-Year Flood and 100-Year Flood**




**Slow rise flooding example**

Resources 2013), a companion report to the CWP, characterized the potential for flood exposure in California. More than 7 million people and $580 billion in assets (crops, buildings, and public infrastructure) currently are exposed in the 500-year floodplains in California. A 500-Year Flood has a 1-in-500, or 0.2 percent, probability of occurring in any given year. A detailed description of flood risks in California can be found in the Flood Future Report available at http://www.water.ca.gov/sfmp/ (California Department of Water Resources 2013).

Today, flood management is evolving from narrowly focused traditional approaches toward an IWM approach. The flood management emphasis has shifted to this more integrated approach that involves a mix of multiple measures, including structural and nonstructural approaches. This more integrated approach enhances the ability of undeveloped floodplains and other open spaces to behave more naturally and absorb, store, and slowly release floodwaters during small and medium events. Flood management as part of an IWM approach considers land and water resources on a watershed scale, employing both structural and nonstructural measures to maximize the benefits of floodplains and minimize loss of life and damage to property from flooding, and recognizing the benefits to ecosystems from periodic flooding. Flood management utilizes best management practices, which are methods or techniques that are used in a variety of circumstances and fields, from stormwater management to land use planning, to yield superior results. The application of flood management approaches within the context of an IWM approach extends the range of strategies that could be employed beyond the traditional strategy. 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), approaches to flood management can serve

**Box 4-2 Flood Management as Part of an Integrated Water Management Approach**

IWM is an approach that combines specific 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 water supply reliability, flood management, and environmental stewardship — 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. IWM acknowledges the importance and function of flooding as a natural part of the ecosystem and helps people to learn to live with and better understand the benefits of flooding. This approach promotes system flexibility and resiliency to accommodate changing conditions such as regional preferences, ecosystem needs, climate change, flood or drought events or financing capabilities.

An IWM approach requires unprecedented alignment and cooperation among public agencies, tribal entities, land owners, interest-based groups, and other stakeholders. It is not a one-time activity but rather an ongoing process. Also, this approach relies on blending knowledge from a variety of disciplines including engineering, planning, economics, environmental science, public policy, and public information.

An IWM approach represents the future of flood management in California with the goal to improve public safety, foster environmental stewardship, and support economic stability.

many purposes. Flood management is a key component of an IWM approach. Box 4-2 provides a description of flood management as part of an integrated water management approach.

## Flood Governance — Policies and Institutions in California

Traditional flood management resulted in a complex network of agencies with overlapping responsibilities. There are more than 1,300 agencies with some aspect of flood management responsibility in California. These responsibilities include planning, administering, financing, and/or maintaining flood management facilities and emergency response programs. Each agency has unique objectives, authorities, roles, responsibilities, and jurisdictions. Agencies include:

- Local, State, federal, and tribal entities (defined as federally recognized tribes and tribal communities).
- Cities, counties, community service areas and districts.
- Drainage and storm drainage districts.
- Flood control districts.
- Irrigation districts.
- Levee protection districts.
- Joint power authorities.
- Public works districts.
- Public utilities districts.
- Reclamation districts.
- Resource conservation districts.
- Sanitation or sewer districts.

- Special districts.
- Water agencies and departments.
- Water conservation districts.

Almost all communities in California have some measure of responsibility for floodplain management, including adopting National Flood Insurance Rate Maps, conforming to the International Building Code, and enforcing building and land use restrictions.

A number of laws were enacted in 2007 regarding flood risk and land use planning. These laws encourage a comprehensive approach to improving flood management by addressing system deficiencies, improving flood risk information, and encouraging links between land use planning and flood management. Many of the requirements established by these laws are applicable only within the Central Valley.

Below is a summary of the legislation.

- **Senate Bill (SB) 5 (2008) Flood Management** requires DWR and the Central Valley Flood Protection Board (CVFPB) to prepare and adopt a Central Valley Flood Protection Plan (CVFPP) by 2012.
- **Assembly Bill (AB) 156 (2007) Flood Control** provides DWR and the CVFPB with specific authorization that would enhance information regarding the status of flood protection in the Central Valley.
- **AB 70 (2007) Flood Liability** provides that a city or county might be responsible for its reasonable share of property damage caused by a flood if the State liability for property damage has increased due to approval of new development after January 1, 2008.
- **AB 162 (2007) General Plans** requires cities and counties statewide to amend the land use, conservation, safety, and housing elements of their respective general plan to address new flood-related matters.

The DWR FloodSAFE initiative created in 2006 consolidated and coordinated DWR's programs for flood management. Two major milestone reports under the FloodSAFE initiative include the 2012 Central Valley Flood Protection Plan (CVFPP) and the Flood Future Report. The CVFPP, which was adopted in June 2012, proposed a systemwide investment approach for sustainable, integrated flood management in areas currently protected by facilities of the State Plan of Flood Control (SPFC). The Flood Future Report identifies flood management issues statewide and presents recommendations to help address the statewide issues.

## Flood Management

Flood management includes a wide range of management actions, which can be grouped into four general approaches: Nonstructural Approaches, Restoration of Natural Floodplain Functions, Structural Approaches, and Emergency Management. These approaches and the management actions within them serve as a toolkit of potential actions that local, State, and federal agencies can use to address flood-related issues and advance IWM.

These actions range from policy or institutional changes to operational and physical changes to flood infrastructure. Such actions are not specific recommendations for implementation; rather, they serve as a suite of generic management tools that can be used individually or combined

**Box 4-3 Case Study Number 1 of Flood Management as Part of an IWM Approach**

An example of a flood related IWM project is the Lower Carmel River Floodplain Restoration and Flood Control Project. The project area is located at a dynamic interface between marine and freshwater systems and serves as a refuge for sensitive species. The agencies involved in this project are the Big Sur Land Trust, Monterey County Water Resources Agency, Monterey County Public Works Department, and California State Parks. This project consists of components that:

- Improve hydrologic functions by reconnecting floodplains through levee setback or removal and land restoration.
- Integrate storage and filtration basins into restored floodplains to increase flood flow retention, promote sediment and nutrient removal, and increase groundwater recharge.
- Conduct geotechnical engineering analyses and hydraulic modeling needed to support design of flood control improvements.
- Modify placement and/or size of existing levees and/or floodwalls, add new levees or floodwalls, construct new bypasses, and restore channel form and function to improve flood protection.
- Develop local flood management plan updates.
- Establish and preserve agricultural operations adjacent to, but hydrologically disconnected from the floodplains.

Project benefits include reduced damage to residences and commercial businesses as well as local and state infrastructure, improved connectivity between the main channel and overbank areas to reduce flooding hazards, installation of a protective buffer against sea level changes, and restored riparian and wetland habitat within the historical floodplain.

for specific application situations. A variety of management actions can be bundled together as part of a single flood management project (see Box 4-3 and Box 4-4, "Case Study of Flood Management as Part of an IWM Approach"). Management actions also can be integrated with other resource management strategies under other objectives (e.g., water supply, water quality, ecosystem restoration, and recreation) to create multi-benefit projects.

Several management actions within flood management are considered to be crosscutting (i.e., they would be a part of all resource management strategies). These crosscutting actions are permitting, policy and regulations, and finance and revenue. Volume 1, *The Strategic Plan*, Chapter 7, "Finance Planning Framework," of Update 2013 provides more details on these potential crosscutting actions, and Table 4-1 describes how these actions relate to improved flood management.

## Nonstructural Approaches

Nonstructural approaches to flood management include land use planning and floodplain management.

### *Land Use Planning*

Land use planning employs policies, ordinances, and regulations to limit development in flood-prone areas and encourages land uses that are compatible with floodplain functions. This can

**Box 4-4 Case Study Number 2 of Flood Management as Part of an IWM Approach**

An example of a flood related IWM project is the flood management, habitat restoration and recharge project on the San Diego River. The project is located in Lakeside in San Diego County and is within a 580-acre area known as the Upper San Diego River Improvement Project. Improvements to the San Diego River and adjacent lands are focused on flood management, environmental habitat restoration, recreation, and water supply. This project consists of components that:

- Improve flood management and water quality as a result of restoration efforts designed to increase the wetlands, improve circulation in the pond, and improve sediment transport.
- Acquire ownership or land tenure on property for preservation or restoration purposes.
- Restore riparian habitat types for several threatened and endangered species.
- Restore the channel including work to improve flood management, restore natural meanders, and lower the 100-year flood level by widening the floodway.
- Implement low-impact development techniques including the use of bioswales to capture and treat urban runoff and improve water quality.
- Capture flood flows for habitat (wetland) enhancement and for groundwater recharge.

Benefits of the project include:

- Reduced flood levels.
- Prevention of urban development in a floodplain, currently subject to development pressure.
- Improved sediment balance.
- Protection of downstream bridges and water pipeline.
- Improved water quality via constructed wetlands to treat urban runoff.
- Increased water supply through groundwater recharge of the aquifer.
- Increased recreation and public access opportunities including camping areas, trails, and a boardwalk in the pond with access for the disabled.

include policies and regulations that restrict or prohibit development within floodplains, restrict size and placement of structures, prevent new development from providing adverse flood impacts to existing structures, encourage reduction of impervious areas, require floodproofing of buildings, and encourage long-term restoration of streams and floodplains.

### *Floodplain Management*

Floodplain management generally refers to nonstructural actions in floodplains to reduce flood damages and losses. Floodplain management includes:

- **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. Communities, State government, and the private sector require accurate, detailed maps to prepare risk assessments, guide development, prepare plans for community economic growth and infrastructure, utilize the natural and beneficial function of floodplains, and protect private and public investments. Development of necessary technical information includes

**Table 4-1 Crosscutting Management Actions and Their Relationship to Flood Management**

| Management Action | Description |
|---|---|
| Permitting | Regional and programmatic permitting methods can provide faster and better delivery of flood management activities including operations, maintenance, repair, habitat enhancement and restoration, and minor infrastructure improvement or construction projects. Regional and programmatic permitting methods can be used to manage permitting needs collectively 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. |
| 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, operation and maintenance, 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. |

topographic data, hydrology, and hydraulics of streams and rivers, delineation of areas subject to inundation, assessment of properties at risk, and calculation of 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. Land acquisition involves acquiring full fee title ownership of lands from a willing buyer and seller. Easements provide limited-use rights to property owned by others. Flood easements, for example, are purchased from a landowner in exchange for perpetual rights to flood the property periodically when necessary or to prohibit planting certain crops that would impede flood flows. Conservation easements can be used to protect agricultural or wildlife habitat lands from urban development. Both land acquisitions and easements generally involve cooperation with willing landowners. Although acquisition of lands or easements can be expensive, they can reduce the need for structural flood improvements that would otherwise be needed to reduce flood risk. Maintaining agricultural uses and/or adding recreational opportunities where appropriate provide long-term economic benefits to communities and the state.
- **Building codes and floodproofing.** Building codes and floodproofing include specific measures that reduce flood damage and preserve egress routes during high-water events.

Building codes are not uniform; they vary across the state based on a variety of factors. Example codes could require floodproofing measures that increase the resilience of buildings through structural changes, elevation, or relocation and the use of flood resistant materials.

- **Retreat.** Retreat is the permanent relocation, abandonment, or demolition of buildings and other structures. Retreat can be used in a variety of settings from floodplains to coastal areas. In coastal regions, this action would allow the shoreline to advance inward and unimpeded in areas subject to high coastal flooding risks, high erosion rates, or future sea level rise. Integrating recreation uses into retreat areas along the shoreline provides economic uses for these buffer lands.
- **Flood insurance.** Flood insurance is provided by the federal government via the 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 subsidized insurance as a protection against flood losses. If a community participates in the voluntary Community Rating System and implements certain floodplain management activities, the flood insurance premium rates are discounted to reflect the reduced flood risks.
- **Flood risk awareness (information and education).** Flood risk awareness is critical because it encourages prudent floodplain management. Flood hazard information is the prerequisite for a sound education in understanding potential flood risks. If the public and decision-makers understand the potential risks, they can make decisions to reduce risk, increase 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.

## Restoration of Natural Floodplain Functions

This approach 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 natural floodplain function restoration is to preserve and/or restore the natural ability of undeveloped floodplains to absorb, hold, and slowly release floodwaters, to enhance the ecosystem, and to protect flora and fauna communities. Natural floodplain function conservation and restoration actions can include both structural and nonstructural measures. 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 the following:

- **Promoting natural hydrologic, geomorphic, and ecological processes.** 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 disrupt natural geomorphic processes, such as sediment erosion, transport, and deposition, which normally cause channels to migrate, split, and rejoin downstream. These natural geomorphic processes are important drivers that create diverse riverine, riparian, and floodplain habitat to support fish and wildlife, and provide natural storage during flood events. Restoration of these processes might be achieved through setting back levees, restoring channel alignment, removing unnatural hard points within channels, restoring flow of sediment that is trapped behind dams, or purchasing lands or easements that are subject to inundation.

- **Protecting and restoring quantity, quality, and connectivity of native floodplain habitats.** In some areas, native habitats and their associated floodplain have been lost, fragmented, and degraded. Lack of linear continuity of riverine, riparian habitats, or wildlife corridors, impacts 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. Creation or enhancement of floodplain habitats can be accomplished through setting back levees and expanding channels or bypasses, or through removal of infrastructure that prevents flood flows from entering floodplains. Coastal wetlands have been severely reduced, resulting in a loss of habitat for freshwater, terrestrial, and marine plant species. Restoration of these habitats could provide a buffer against storm surges and sea level rise.
- **Invasive species reduction.** Invasive species can reduce the effectiveness of flood management facilities by decreasing channel capacity, increasing rate of sedimentation, and increasing maintenance costs. Reductions in the incidence of invasive species can be achieved by defining and prioritizing invasive species of concern, mapping their occurrence using BMPs for control of invasive species, and using native species for restoration projects.

## Structural Approaches

Structural approaches to flood management include flood infrastructure, reservoir and floodplain storage and operations, and operations and maintenance (O&M). When local entities are a partner on any federal project, the sponsor has to agree to operation, maintenance, repair, rehabilitation, and replacement (OMRR&R), which goes beyond the requirements of O&M.

### *Flood Infrastructure*

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

- **Levees and floodwalls.** Levees and floodwalls are designed to confine flood flows by containing waters of a stream or lake. Levees are an earthen or rock berm 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 stream edges, or farther back (e.g., a setback levee). Ring levees could be constructed around a protected area, isolating the area from potential floodwaters.
- **Channels and bypasses.** Channels and bypasses convey floodwaters to reduce the risk of 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 with concrete, riprap, or other materials to increase drainage efficiency. Channel modifications can result in increased erosion downstream, degradation of adjacent wildlife habitat, and often require extensive permitting. Bypasses are structural features that divert a portion of flood flows onto adjacent lands or into 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 generally have a permanent pool of water and may 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, shoreline stabilization, and streambank stabilization.** Coastal armoring structures and shoreline stabilization reduce risk to low-lying coastal areas from flooding. Coastal armoring structures are typically 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. Streambank stabilization protects the banks of streams from erosion by installing riprap, matting, vegetation, or other materials to reduce erosion.
- **Debris mitigation structures.** When debris and alluvial flooding occur, Sabo dams, debris fences, and debris basins separate large debris material from debris flows, or they contain debris flows above a protected area. These structures require regular maintenance to periodically remove and dispose of debris after a flood. Deflection berms or training berms can be used to deflect a debris flow or debris flood away from a development area, allowing debris to be deposited in an area where it would cause minimal damage.

### *Reservoir and Floodplain Storage and Operations*

- **Reservoir and floodplain storage.** These provide an opportunity to regulate flood flows by reducing the magnitude of flood peaks occurring downstream. Many reservoirs are multipurpose and serve a variety of functions including water supply, irrigation, habitat, and flood control. Reservoirs collect and store water behind a dam and release it after a storm event. Floodplain storage occurs when peak flows in a river are diverted to adjacent offstream areas. Floodplain storage can occur naturally when floodwaters overtop a bank and flow into adjacent lands, or storage can be engineered using weirs, berms, or bypasses to direct flows onto adjacent lands.
- **Storage operations.** This optimizes the magnitude and timing of reservoir releases. 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 to revise reservoir release operations based on advanced weather and hydrology forecasts, or it can simply involve participation in coordination meetings during flood emergencies.

### *Operations and Maintenance*

O&M is a crucial component of flood management. O&M activities can include inspection, vegetation management, sediment removal, management of encroachments and penetrations, repair or rehabilitation of structures, or erosion repairs. Because many flood facilities constructed in the early to mid-20th century are near or have exceeded the end of their expected service lives, adequate maintenance is critical for these facilities to continue functioning properly.

## Flood Emergency Management

Flood emergency management includes the following activities:

- **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. Preparing for floods can also include modifying or restricting new development in floodplains, removing existing structures that are the most at risk, and restoring natural floodplains.
- **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 timely notification of responsible authorities so that plans for evacuation of people and property can be implemented. Emergency response includes flood fighting, emergency evacuation, and sheltering. Response begins with, and might be confined to, affected local agencies or operational areas (e.g., counties). Depending upon the intensity of the event and the resources of local responders, response from regional, State, and federal agencies might be required.
- **Post-flood recovery.** Flood recovery programs and actions include restoring utility services and public facilities, repairing flood facilities, draining flooded areas, removing debris, and assisting individuals, businesses, and communities to return to normal. Recovery planning could include development of long-term floodplain reconstruction strategies to determine if reconstruction would be allowed in flood-prone areas, or if any existing structures could be removed feasibly. Such planning should review what building standards would be required, how the permit process for planned reconstruction could be improved, funding sources to remove existing structures, natural habitat restoration, and how natural floodplains and ecosystem functions could be incorporated.

## Connections to Other Resource Management Strategies

An IWM approach relies on the application of multiple strategies. In addition to the flood-specific strategies, other water resource management strategies included in the Update 2013 have the potential to provide flood management benefits and may be incorporated as an element of an IWM approach.

Resource management strategies that share important synergies with flood management are described briefly below.

- **Land use planning and management.** One of the most effective ways to reduce the vulnerability to potential flooding is through careful land use planning that is fully informed by applicable flood information and flood management practices. Land use policies that encourage locating new development outside floodplains can reduce flood risks. Land use policies that encourage compact development and low-impact development can reduce flood volumes and peaks. In addition, nonstructural approaches to flood management can reduce flood risk to both existing and future development.
- **Sediment management.** Floods have a major role in transporting and depositing unconsolidated sediment onto floodplains. Erosion and deposition help in determining the shape of a floodplain, the depth and composition of soils, the quality of river habitats, and the type and density of vegetation. Disruption of the dynamics of natural sediment transport can cause failure of adjacent levees through increased erosion or can reduce the flood-carrying

capacity of natural channels through increased sedimentation. Sediment is a major component of alluvial fan and debris-flow flooding.

- **Watershed management.** Watersheds are an appropriate organizing unit for managing floodplains. Restoring, sustaining, and enhancing watershed functions are key goals of flood management in the context of IWM.
- **Urban stormwater runoff management.** Urbanization creates impervious surfaces that reduce infiltration of stormwater and can alter flow pathways along with the timing and extent of flooding. Impervious surfaces increase runoff volumes and velocities, which result in streambank erosion and potential flooding problems downstream. Urban runoff can pick up a variety of pollutants from the ground before it enters streams, rivers, and coastal waters. However, watershed approaches to urban runoff management can capture, treat, and use urban runoff for beneficial uses in a manner that mimics a natural hydrologic cycle.
- **Agricultural land stewardship.** Due to flat topography and rich soils caused by historical flood deposits, floodplains are often ideal for agricultural uses. Agricultural runoff can carry pollutants, such as fertilizers, into the water system. However, responsible stewardship of agricultural lands can prevent urban development within floodplains, constraining farming and ranching practices to those areas that are compatible with floodplain management. Innovative funding mechanisms like flood easements can be used to compensate farmers who allow their fields to be flooded during extreme events.
- **Forest management.** Forestry practices can influence not only sediment transport from upland streams, but also the timing and magnitude of peak flows. The high amount of surface roughness in forested floodplains reduces floodwater velocities, spreads flows across a larger area of the floodplain, and attenuates downstream flows. Catastrophic wildfires can increase peak flows and reduce surface water infiltration, which can cause erosion and debris flooding. Forest management to reduce catastrophic wildfires is an important action to minimize flood damages.

Resource management strategies that are also management actions directly contributing to flood management include the following:

- **Conveyance.** Many streams and channels are used to support both flood flow conveyance and water supply conveyance. Improvements to regional water supply conveyance systems could enhance the potential for flood flow conveyance, and vice versa.
- **Surface storage.** Most of California's major surface water reservoirs are managed for multiple purposes including water supply, hydropower, water quality, recreation, and ecosystem needs as well as flood management. Increasing local and regional surface storage has the potential to provide greater water management flexibility for capturing runoff and controlling flood flows.
- **System reoperation.** The primary goal of forecast-coordinated and forecast-based operations is to improve downstream flood protection while improving, or at least not degrading, water supply, environmental, or recreational uses through better hydrologic forecasting and coordinated reservoir operations.
- **Outreach and engagement.** Regular outreach is needed to inform the public regarding flooding, flood risks, floodproofing, and impacts of climate change, as well as to explain what households, businesses, and communities can do to reduce or mitigate risk to acceptable levels. Outreach is also needed to inform the public regarding natural beneficial functions of floodplains.

Resource management strategies that could directly benefit from natural functions of flooding include the following strategies:

- **Ecosystem restoration.** Floodplain environments are dynamic in nature and are highly productive biological communities, given their proximity to water and the presence of fertile soils and nutrients. California native riparian and aquatic animal and plant communities are adapted to conditions of seasonal flooding. Many other terrestrial plants and animals use riparian areas for forage and movement across the landscape. The principal opportunities for improvement in both flood management and ecosystem restoration occupy the same spatial footprint and are affected by the same physical processes that distribute water and sediment in rivers and across floodplains.
- **Pollution prevention.** Floodplains that function well improve water quality by filtering impurities and nutrients, processing organic wastes, controlling erosion and sedimentation of streams, and moderating temperature fluctuations.
- **Water-dependent recreation.** Protecting and enhancing public access to rivers, lakes, and beaches increases public safety, fosters environmental stewardship, and increases economic sustainability of flood management projects. Flood management infrastructure must be designed to protect public trust uses such as navigation and recreational access to the state's waterways and beaches. Flood protection facilities, natural floodplains, and restored areas can improve recreational access to waterways by providing opportunities for integrating suitable recreation facilities.
- **Recharge area protection, conjunctive management, and groundwater storage.** Diversions of flood flows for groundwater infiltration can reduce downstream flooding and improve water supply by storing groundwater as well as providing water for conjunctive use. The generally flat topography of natural floodplains and the permeable nature of alluvial soils promote infiltration into the subsurface for storage in soils and aquifers.

## Potential Benefits

Primary benefits of flood management are derived from the potential to reduce risks to lives and property from flood events and increase flood resilience, which reduces social and economic disruption and flood recovery costs. Flood management also provides beneficial opportunities for water supply, environmental management, water quality, recreation, hydropower, and navigation. Potential benefit categories are discussed briefly in the following subsections. Table 4-2 provides a summary of potential benefits and costs of the specific flood management strategies and management actions.

### Flood Risk Reduction Benefits

The importance of flood risk reduction to promote public safety and economic stability cannot be understated. More than seven million people and $580 billion in assets (crops, buildings, and public infrastructure) are currently exposed in 500-year floodplains in California (California Department of Water Resources 2013). Many areas in California lack even basic protection from a 100-year flood. Flood management approaches decrease this risk by decreasing the probability of flooding and the consequences from flooding using a wide variety of actions. Flood infrastructure, operations, and maintenance can reduce the frequency, extent, and depth of flooding. Floodplain management and land use planning, building resiliency into the system along with emergency preparedness, response, and recovery, further reduce residual risks that

**Table 4-2 Benefits and Costs of Management Actions**

| Management Action | Flood Risk Reduction Benefits | Potential Integrated Water Management Benefits | | | | | | Costs[a] |
|---|---|---|---|---|---|---|---|---|
| | | Water Supply | Environmental | Recreation | Water Quality | Hydropower | Navigation | |
| **Non-Structural Approaches** | | | | | | | | |
| **Land use planning** | Addresses all types of flooding. Reduces risk by reducing what is flooded. No reduction in residual risk. | X | X | X | X | | | Low initial costs. No significant change to annual costs. |
| **Floodplain management**<br><br>Floodplain mapping and risk assessments | Addresses all types of flooding. Could reduce flood risk if risk assessment leads to land use decisions that are consistent with floodplain mapping data. | | | | | | | Low initial costs. Low to medium annual costs. |
| Land acquisitions and easements | Addresses all types of flooding. Reduces risk by reducing what is flooded. No redirected hydraulic impacts or reduction in residual risk. | X | X | X | X | | | High initial costs based on location, extent, or type of easement. Costs include real estate acquisitions, relocations, mitigation, engineering, and permitting. Annual costs vary. |
| Building codes and flood proofing | Addresses all types of flooding. Reduces what is flooded and the susceptibility of people and property from harmful flooding. Reduces residual risk. | | | | | | | Low initial costs for building code changes and costs for implementation could be recovered through additional fees. Medium to high initial costs for flood proofing depending on number of structures. |
| Synonymous retreat | Addresses coastal flooding by reducing what is flooded and the susceptibility of people and property from harmful flooding. Reduces residual risk. | | X | X | | | | Medium to high initial costs depending on type of retreat, location, extent, type of structure, real estate acquisitions, mitigation, and permitting. |

| Management Action | Flood Risk Reduction Benefits | Potential Integrated Water Management Benefits | | | | | | Costs[a] |
|---|---|---|---|---|---|---|---|---|
| | | Water Supply | Environmental | Recreation | Water Quality | Hydropower | Navigation | |
| Flood insurance | Addresses all types of flooding. Improves the recovery of people and property from harmful flooding. Reduces residual risk. | | | | | | | Low to medium initial costs. Low annual costs. |
| Flood risk awareness – information and education | Addresses all types of flooding. Does not directly reduce flood risk, but reduces what might be flooded if it leads to land use decisions that are consistent with floodplain function. Reduces residual risk. | | | | | | | Low initial costs. Low to medium annual costs depending on extent of training and how flood information is disseminated. |
| **Natural floodplain function restoration**<br><br>Natural hydrologic, geomorphic, and ecological processes | Addresses all types of flooding. Can reduce peak flood flows and decrease the frequency, extent, and depth of flooding. No change in residual risk. | X | X | X | X | | | Medium to high initial costs based on size of project, real estate acquisitions, relocations, permitting, design, construction, mitigation, and loss of property taxes. Annual O&M costs could increase during establishment period, but would be reduced over long term. |
| Quantity, quality, and connectivity of native floodplain habitats | Does not directly reduce flood risk. Can provide mitigation opportunities for habitat losses elsewhere for flood management. No changes in residual risk. | X | X | X | X | | | Highly variable initial costs depending on type of effort, real estate acquisitions, relocations, permitting, design, construction, and potential loss of property taxes. Annual costs could increase short term, but would decrease long term. |

| Management Action | Flood Risk Reduction Benefits | Potential Integrated Water Management Benefits | | | | | | Costs[a] |
|---|---|---|---|---|---|---|---|---|
| | | Water Supply | Environmental | Recreation | Water Quality | Hydropower | Navigation | |
| Invasive species | Addresses all types of flooding. Reduces the probability, extent, and depth of flooding by decreasing channel capacity and increasing rate of sedimentation. | | X | X | | | | Medium initial costs with potential costs related to permitting, maintenance, mapping, and technical evaluation on how to control invasive species. Annual maintenance costs would increase slightly. |
| **Structural Approaches** | | | | | | | | |
| **Flood infrastructure**<br><br>Levees and floodwalls | Addresses all types of flooding by reducing the frequency of flooding. Reduces the susceptibility of people and property from harmful flooding. If development is encouraged behind levees, residual risk would increase. | [b] | [b] | X | | | | High initial costs depending on location, number of levees or floodwalls, real estate needs, permitting/mitigation costs. Additional annual O&M costs required. |
| Channels and bypasses | Predominantly addresses slow-rise and flash flooding. Reduces the susceptibility of people and property from harmful flooding. | X | X | X | | | X | High initial costs depending on location, number of channels or bypasses, real estate needs, permitting/mitigation costs. Additional annual O&M costs required. |
| Retention and detention basins | Predominantly addresses slow-rise and flash flooding. Reduces the susceptibility of people and property from harmful flooding. | X | | | X | | | High initial costs depending on location, amount, real estate needs, permitting/mitigation costs. Additional annual O&M costs required. |
| Culverts and pipes | Predominantly addresses slow-rise and flash flooding. Reduces the susceptibility of people and property from harmful flooding. | | | | | | | High initial costs depending on location, amount, real estate needs, permitting/mitigation costs. Additional annual O&M costs required. |

| Management Action | Flood Risk Reduction Benefits | Potential Integrated Water Management Benefits | | | | | | Costs[a] |
|---|---|---|---|---|---|---|---|---|
| | | Water Supply | Environmental | Recreation | Water Quality | Hydropower | Navigation | |
| Coastal armoring structures, shoreline, and streambank stabilization | Addresses coastal flooding by reducing the frequency of flooding and reducing erosion rate. Reduces the susceptibility of people and property from harmful flooding. If development is encouraged behind armoring structures and shoreline stabilization, residual risk would increase. | | [c] | [c] | | | | High initial costs depending on location, amount, real estate needs, permitting/mitigation costs. Additional annual O&M costs required. |
| Debris mitigation structures | Addresses debris and alluvial fan flooding by retaining debris and reducing downstream flooding. Reduces the susceptibility of people and property from harmful flooding. | | | | X | | | Medium-high initial costs. High annual O&M costs for debris removal and disposal. |
| **Reservoir and floodplain storage and operations**<br><br>Reservoir and floodplain storage | Addresses slow-rise and flash flooding. Reduces the probability, extent, and depth of flooding. Reduces frequency of flooding and residual risk by reducing peak flows. | X | X | X | | X | | Medium to very high initial costs depending on location and size of storage, real estate acquisitions, relocations, permitting/mitigation costs, complexity of facilities. Additional small annual O&M costs. |
| Storage operations | Addresses slow-rise and flash flooding by reducing frequency and magnitude of downstream flooding and reducing residual risk. Reduces the probability, extent, and depth of flooding. Coordinated operations can involve transfer of risk, increasing risk in one area, while decreasing risk in another. | X | X | X | | X | | Low-medium initial costs depending on location, extent of facilities, forecasting and hydrologic technology used. Annual costs are variable. |

| Management Action | Flood Risk Reduction Benefits | Potential Integrated Water Management Benefits | | | | | | Costs[a] |
|---|---|---|---|---|---|---|---|---|
| | | Water Supply | Environmental | Recreation | Water Quality | Hydropower | Navigation | |
| **Operations and maintenance** | Addresses all types of flooding. Reduces vulnerability of flood infrastructure. No change in residual risk. | | X | | | | [d] | Low initial costs. Medium to high annual costs depending on type and extent of maintenance. |
| **Flood emergency management**<br><br>Flood preparedness | Addresses all types of flooding. Reduces the susceptibility of people and property from harmful flooding. Reduces residual risk by reducing the consequences of flooding. | | | | | | | Low to medium initial costs. Low annual costs. |
| Emergency response and flood fighting | Addresses all types of flooding. Reduces the susceptibility of people and property from harmful flooding. Reduces residual risk by reducing the consequences of flooding. | | | | | | | Low to medium initial costs. Low annual costs. |
| Post-flood recovery | Addresses all types of flooding. Does not directly reduce flood risk, but improves public safety in the aftermath of a disaster. | | | | | | | Low to medium initial costs. Low annual costs. |

Notes:

[a] The costs defined in this table are in relative terms. No actual number value can be placed on the costs due to the site-specific nature of the management actions. The terms low, medium, and high are used to give a comparison between the management actions and not for budgetary or costing purposes.

[b] Setback levees

[c] Natural and artificial reefs

[d] Dredging

cannot be reduced by infrastructure alone. Limiting development in floodplains helps address the primary source of flood risk instead of merely addressing its symptoms. Without these risk-reduction measures, a major flood has the potential to catastrophically affect millions of residents, homes, businesses, and agricultural lands; cause critical infrastructure to go out of service for long periods of time; and isolate or close off vital services.

## Integrated Water Management Benefits

An IWM approach is a crosscutting benefit that bundles management actions based on systemwide needs. Flood management as part of an integrated approach can leverage flood management benefits from a variety of projects and programs, including those focused on other forms of water resources management. There are several cost advantages of an IWM approach due to improved delivery and implementation of flood management. Improved agency interaction through an IWM approach is at the core of implementing these advantages because a diverse set of stakeholders must coordinate, cooperate, and collaborate to develop successful IWM projects. Improved agency interaction also facilitates effective planning, agency alignment, and identification of investment priorities and funding. A key benefit of agency alignment for flood management is reduced permitting and mitigation process costs as well as improving governance and policy.

Agency alignment at all levels (local, State, and federal agencies, as well as tribal entities) also enables completion of statewide planning that helps identify governance and policy needs required to develop statewide investment priorities. Setting statewide investment priorities encourages development of integrated projects and increases the pool of available funding, making funding more reliable. Local, State, and federal agencies and tribal entities are beginning to structure their flood management programs to support multiple-benefit projects. These multiple-benefit projects have access to different or new funding sources. Partnering with other agencies can increase flexibility for pursuing diverse funding sources to overcome grant caps and varied eligibility requirements. Coordination across geographic and agency boundaries can help agencies pool and leverage their funding to make the best use of limited human and financial resources.

## Water Supply Benefits

An integrated approach to flood management would maximize the beneficial uses of water to improve water supply reliability, stormwater management, and groundwater recharge. An IWM approach to flood management would increase water supply reliability by improving the operational flexibility of multipurpose infrastructure, such as channels and bypasses, that are used for water supply and floodwater conveyance, and multipurpose reservoirs to store floodwaters that are used later for water supply. The restoration of natural floodplain functions by reconnecting streams to their historical floodplains, setting back levees, creating floodplain storage, and acquiring easements would encourage natural groundwater recharge by providing an expansive area where floodwaters would slow in velocity, disperse over a broader area, and infiltrate into the ground.

## Environmental Benefits

An integrated approach to flood management would enhance ecosystems by restoring the natural hydrologic, geomorphic, and ecologic processes and by improving the quantity, quality, and connectivity of riverine and coastal habitats. These actions result in healthier, self-sustaining ecosystems that provide breeding and feeding grounds for a wide variety of aquatic and terrestrial species. Such actions also help maintain the diversity of plants and animals by aiding in the recovery of endangered and threatened species and controlling invasive species. These actions also increase ecosystem resiliency to uncertain changing conditions such as climate change. Integrating ecosystem conservation and restoration with flood risk-reduction projects is an essential component of flood management that can increase effectiveness, sustainability, and public support. Restoration of natural floodplain functions to attenuate peak flows would include benefits to natural watershed.

## Water Quality Benefits

Restoration of natural floodplain functions as part of a flood management strategy would improve water quality by filtering nutrients and impurities from runoff, which reduces levels of pathogens and toxic substances. Restored natural floodplain functions would help process organic wastes, control erosion and sedimentation by stabilizing banks, and moderate temperature fluctuations by planting trees to provide shade. Infrastructure, such as debris mitigation structures, can improve water quality by reducing the amount of sediment from debris flooding.

## Recreation Benefits

Integration of flood management and recreation can increase the number and quality of recreational areas and parks for water-oriented sports, boating, swimming, hiking, and camping. Floodplain management through land use planning and ecosystem restoration can support recreational activities by providing areas of active- and passive-use recreation in floodplains and flood greenways, increasing open space, and increasing scenic value. Even in urban areas, establishing greenways as part of flood management projects and replacing concrete channels with more natural creek environments can satisfy recreation demand. Recreation provides communities with economic and public health benefits while supporting the economic, environmental, and social sustainability of flood management projects.

## Hydropower Benefits

California's major surface water reservoirs that are intended for flood management generate hydropower or are hydraulically connected to reservoirs that generate hydropower. Optimizing storage operations provides more water management flexibility to achieve multiple benefits, including hydropower generation.

## Navigation Benefits

Several channels and bypasses in California that are subject to flooding provide navigation benefits when used for interstate commerce. Channel dredging operations to increase channel capacity can also provide navigation benefits.

## Potential Costs

Since Update 2009, DWR has worked to identify the costs of improving flood management on a statewide basis. Included in this effort are the CVFPP, the Flood Future Report, and regional flood management through integrated regional water management (IRWM) plans. Collectively, these efforts identified the immediate need for more than $50 billion to complete flood management improvements and projects. These flood management projects include maintenance projects and other identified actions. The Flood Future Report also indicated the need for substantial additional funding to complete flood risk assessments throughout the state, and to conduct flood management improvements based on those assessments. Therefore, the total estimated capital investment needed for flood management projects could easily top $100 billion (California Department of Water Resources 2013). These estimates do not include the broader regional economic impacts or ripple effects of flooding, such as the costs resulting from rerouting traffic and closing businesses, and from compromised services of water and wastewater treatment plants, as well as critical facilities such as hospitals. These losses of function have a wider impact that can range from regional to statewide, nationwide, or even international. For example, if flood damages disrupted the delivery of water for a significant amount of time, the economic impacts would be substantial, with the effects reaching 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.

The costs of different management actions vary significantly. For example, developing a new reservoir can cost billions of dollars, but some policy and regulatory management actions can be implemented for minimal investments of time and money. IWM projects can sometimes cost more in advance to implement. However, thoughtful planning can leverage different funding streams and provide multiple benefits over the project's useful life, sometimes reducing overall project costs. In addition to the initial costs for an action, provisions must be made for long-term operations and maintenance (O&M). Costs for implementing a single management action can also vary widely based on quantity, location, real estate costs, permitting and mitigation costs, and other factors. Therefore, potential costs for flood management actions are summarized qualitatively in Table 4-2. Initial and annual costs for each management action were characterized with a low, medium, or high value, which represents the relative cost of the management action compared to other flood management actions.

Nonstructural measures, such as land use planning and floodplain management, are some of the most cost-effective strategies for reducing flood risk over the short and long term. It is more economical to invest in information and education efforts that help keep people and property out of floodplains than to invest in flood infrastructure. Constructing flood infrastructure requires significant up-front capital investment and long-term funding for operations and maintenance.

Multiple benefit projects often have higher initial costs than narrowly focused projects, which can sometimes be a barrier to their implementation. However, an IWM project can achieve economies of scale while meeting multiple resource management goals with less cost and a smaller footprint. An integrated approach can also leverage flood management benefits from a variety of projects and programs, including those focused on other forms of water resources management.

Higher initial and short-term costs of IWM projects can be offset sometimes by benefits that accrue time. For example, setting back a levee to reconnect the channel with the floodplain and promoting natural floodplain functions can have higher initial costs than a fix-in-place levee

improvement. However, incorporating the setback levee can decrease project delays as well as reduce regulatory compliance, long-term operations, maintenance, and repair costs. Setback levees can also provide long-term benefits to water supply and the environment by increasing groundwater infiltration and providing habitat restoration opportunities.

## Climate Change Considerations and Implications

Climate change will have a significant impact on the timing and magnitude of precipitation and runoff and contribute to a rise in sea levels. Increased air temperatures will result in more precipitation falling as rain rather than snow, contributing to increases in winter runoff. While future precipitation is somewhat uncertain, greater flood magnitudes are anticipated due to more frequent atmospheric river storms and other extreme weather events (Dettinger 2011). In addition, rising sea levels could increase the potential for high tides and storm surges to inundate low-lying coastal areas. Warmer temperatures and changes in soil moisture are expected to contribute to more frequent and intense wildfires. Areas damaged by these wildfires would have a greater potential for flooding associated with accelerated runoff and debris flows. Such changes could affect the magnitude and frequency of flood events, although specific effects would be difficult to predict reliably.

Understanding the specific effects of climate change is a significant data gap. For example, much of the current analysis of climate and water impacts considers how changes in various mean conditions (e.g., mean temperatures, average precipitation patterns, mean sea level) will affect water resources, particularly California's water supply. Although many water resource factors are affected by such average conditions, some of the most important impacts, including flooding, will result not from changes in averages, but from changes in local extreme precipitation and runoff events over short periods (California Department of Water Resources 2006). These extremes are difficult to predict because climate projections from global climate models have difficulty representing regional- and local-scale precipitation patterns and processes that drive extreme events over short time steps (e.g., hours or days). Without this information, flood planners and emergency managers have a difficult task making informed decisions about the impacts and risks of climate change.

### Adaptation

The impacts of climate change can be addressed through adaptation and mitigation measures. Anticipated changes in runoff, frequency and magnitude of flood events, and sea level rise present serious challenges to flood management. However, many of the approaches presented in the flood management actions, such as setback levees, reservoir operations, floodplain management, land acquisition/easements, retreat, and restoring ecosystem functions, can assist in providing more flexibility and resiliency in adapting to a changing climate. For example, levee setbacks and bypasses can provide greater protection from anticipated changes in the timing and magnitude of precipitation and runoff, as well as changes in storm intensities that are expected by improving flow capacity.

Incorporating climate change considerations into land use and emergency management planning decisions can also play a key role in flood management. For example, decisions to avoid developing in areas particularly vulnerable to sea level rise or retreating from them would greatly

reduce the risk of flooding and/or the need for new or larger levees, seawalls, coastal armoring, or other flood infrastructure.

### Mitigation

Mitigation is accomplished by reducing or offsetting greenhouse gas emissions in an effort to lessen contributions to climate change. Structural approaches to flood risk management are often the most energy-intensive actions that cause increased greenhouse gas emissions from the building and maintenance of infrastructure. In contrast, nonstructural approaches, such as land use planning and floodplain management, require less energy and emit fewer greenhouse gas emissions. Floodplain restoration can also aid in mitigating climate change through carbon sequestration in soil and vegetation or riparian restoration.

## Major Implementation Issues

Major issues and challenges to implementing flood management as part of an IWM approach were identified in the Flood Future Report, based upon interviews with more than 140 local, State, and federal agencies, and tribal entities, with varying levels of flood management responsibilities in each county. Additional issues have been identified by land use and environmental planners, and others with flood management responsibility. Together, these issues represent the following primary barriers related to implementation of flood management in the context of IWM:

- Issue 1: Inadequate and unstable funding and incentives.
- Issue 2: Inadequate data/information and inconsistent tools.
- Issue 3: Inadequate public and policy-maker awareness of flood risk.
- Issue 4: Complex and fragmented governance structure impeding agency alignment and systems approach (California Department of Water Resources 2013).

### Issue 1: Inadequate and Unstable Funding and Incentives

Current funding for flood management is inadequate and unreliable because it is dependent upon agency user fees, assessments, bond funding, and earmarking. Flood management program funding has been cyclical, often increasing following a flood disaster, then gradually decreasing as other priorities garner the attention of residents and policy-makers. Local funding is linked to city and county revenue and is affected by changes in the state's economy. State funding has been heavily dependent on bond funds, and to some extent the fluctuations of the General Fund. Funding of flood management for local agencies is hampered by Propositions 13 and 218, which restrict an agency's ability to increase property assessments. Funding from assessments or impact fees can have limitations on where the funds can be spent geographically. For example, upstream infrastructure that decreases downstream risk could not be funded in a flood management assessment district because the infrastructure is not within the district's geographic boundary. Flood management budgets are especially susceptible to reductions in dry years or economic downturns. State bond funding will be depleted by 2017, and the federal spending on flood management is uncertain, but is unlikely to continue at the same levels as in the past.

Funding for flood management, as well as funding for an IWM approach, is inadequate to meet current needs. Funding sources and incentives have changed over time. In addition, agencies involved in flood management do not have clear and strong incentives from State and federal governments to implement regional/systemwide planning and multi-benefit solutions. Financial incentives provided to local agencies traditionally have not distinguished between supporting narrow-purpose projects implemented by a single agency and multi-benefit projects implemented on a regional scale. Providing adequate incentives for an IWM approach to flood management is important because it requires investments of time, energy, and staff resources for the required coordination to achieve long-term benefits.

Also, new regulations place additional requirements on projects. For example, the California Water Code Sections 12840-12842 stipulate that "recreational development should be among the purposes of all federal flood control and watershed protection projects." This regulation requires broad-based public funding of recreational opportunities associated with many types of flood control projects. As with the Davis-Dolwig Act, the State has struggled to establish a funding strategy to provide for planning, construction, operation, and maintenance of these facilities to "achieve the full utilization of such projects for recreational purposes."

## Issue 2: Inadequate Data/Information and Inconsistent Tools

Improved quantity, quality, and accessibility of data are needed in large areas of the state to close data gaps related to flood risk, floodplain mapping, hydrologic data, flood infrastructure integrity, ecosystem mapping, flood forecasting, flood readiness, and climate change.

Inadequate and outdated hydrologic and mapping data hinder assessments of flood risk across the state. Accurate and detailed mapping is needed to guide development, prepare plans for community economic growth and infrastructure, utilize natural and beneficial functions of floodplains, and protect private and public investments. The condition of aging infrastructure is sometimes not fully understood and can be expensive to assess. Funding is often inadequate to meet current data, assessment, and mapping needs.

A need also exists to increase the quality of environmental information and tools for informing flood management and conservation activities. Even in cases where data and information are available, variable conditions, such as climate change, add new uncertainties to existing data sets. Although much information is available online about flood management including data, case studies, budget information, funding sources, climate change, and other planning tools, many data repositories have differing levels of accessibility, ease of use, and metadata requirements. Although these data exist, the sources are difficult to locate and access and data may be inconsistent.

Other major data gaps exist that inhibit a consistent methodology to assess flood risk and measure project benefits. Different methods are used across the state to assess flood risk, which yields inconsistent results. The methods include those used by the U.S. Army Corps of Engineers (USACE), FEMA, and local agencies. Each of these methods were developed to reach unique objectives that required different levels of complexity. For example, FEMA uses an approach that has traditionally focused on hazards associated with 100-year and 500-year flood events, in contrast to USACE approach that assesses and describes risk in terms of expected annual damage (EAD). Many of the benefits that are reaped using an IWM approach cannot be quantified monetarily, which hampers assessing and comparing different integrated solutions. It is especially

difficult to assign a value to ecosystem restoration benefits. No set methodology exists to measure such benefits, resulting in an under-valuation of the benefits of IWM.

### Issue 3: Inadequate Public and Policy-Maker Awareness and Understanding of Flood Risk

Policy-makers and the public have varying levels of understanding about risks and consequences of flooding. Lack of awareness and understanding can increase risks to people and property and make it difficult to achieve sustainable, long-term planning and investment that supports flood management. Currently, many California residents and policy-makers are primarily aware of risk of flooding based on the need to purchase flood insurance under FEMA's NFIP. This program and the use the of terms 100-year and 500-year floods, leads many people to mistakenly believe that protection from a 100-year flood means that their home will not be flooded for 100 years. Actually, a 500-year flood has a 1-in-500 probability of occurring in any given year (0.2 percent annual chance) and a 100-year flood has a 1-in-100 probability of occurring in any given year (1 percent annual chance). These flood event levels indicate a percentage of probability and severity, but they do not mean that such a flood would happen only once every 100 or 500 years. Policy-makers need updated data, including maps, to help make better decisions. Also, residents and policy-makers rely on the infallibility of flood infrastructure, including levees, and are often unaware of consequences that occur outside floodplains (e.g., economic impacts, loss of critical services).

Another barrier to understanding is that flood risk is a dynamic and complex topic because it is impacted by changes in hydrology (including climate change uncertainties), reliability of the data used to assess flood hazards, reliability of flood management structures, and changes in the consequences of a flood event. Changes in any of these factors can greatly change a community's flood risk over time.

In addition, major floods are infrequent, they occur many years apart, and this results in the public underestimating flood risk. Policy-makers responsible for land use decisions need updated information and data from the State and FEMA in order to make better decisions that avoid putting people and assets at risk. This lack of awareness makes it difficult to achieve sustainable, long-term planning and investment that support flood management and even more difficult to gain public understanding of flood risks.

### Issue 4: Complex and Fragmented Governance Structure Impeding Agency Alignment and Systems Approach

Responsibilities for flood management are currently fragmented across numerous local, State, and federal agencies and tribal entities. Flood management is often complicated by the large number of agencies and entities involved, and by their complex jurisdictional roles and responsibilities. More than 1,300 agencies have some aspect of flood management responsibility in California. Each of these agencies has unique objectives, authorities, roles, responsibilities, and jurisdictions. The fragmentation of flood management responsibilities results in poor agency alignment. Overlapping jurisdictions and conflicting missions and priorities across various local, State, and federal agencies and tribal entities involved in flood management can lead to inconsistent policies, regulations, enforcement, and practices. Coordinating activities within this fragmented jurisdictional landscape can be challenging, particularly for local entities. There is a strong need

for improved agency alignment through coordination of policies and guidance across multiple agencies at all levels – local, State, federal, and tribal.

The complex and fragmented governance structure in California hinders and sometimes precludes agency alignment. Agency alignment is cooperation and collaboration toward a common IWM approach. There are agency coordination issues that are both intragency and interagency, as well as coordination with regulatory and resource agencies. Improper agency alignment results in projects that are narrowly focused, miss opportunities for integration and funding maximization, and projects that have unintended negative impacts on downstream or upstream communities and natural environments. Most flood management agencies in California understand the benefits of an IWM approach, but might not have the authority or resources to participate in projects that are regional or systemwide in scale.

Another consequence of improper agency alignment is inconsistent regulatory requirements, permitting processes, and enforcement practices. Unclear, conflicting, or mutually exclusive regulatory objectives or requirements can increase costs and time needed for regulatory review. Lack of consistent standards for mitigation requirements can impede project development and implementation. This can result in conflicts between competing project objectives.

Agency alignment is essential for establishing clear roles and responsibilities related to emergency preparedness, response, and recovery. This lack of alignment, as well as concerns about funding and cost reimbursement, can result in confusion or inaction during a flood emergency.

## Recommendations

Recommendations to facilitate implementation of flood management initiatives have been developed in response to the four major issues identified above. These recommendations are organized by the need to:

- Pursue stable funding and create incentives.
- Develop and disseminate adequate data and tools.
- Improve public and policy-maker awareness and understanding of flood risk.
- Strengthen agency alignment.

### Pursue Stable Funding and Create Incentives

1. **Federal and State agencies should link funding to using an IWM approach by 2017.** Providing incentives for an IWM approach with State and federal funds will encourage local agencies to implement higher-value, multi-benefit projects when developing options for flood management. This effort could include providing incentives to all agencies and tribal interests for regional- or systemwide-scale flood management planning that encompasses conservation and restoration, including riverine, floodplains, and other ecosystem functions. Performing planning at this broader scale for flood management enables a more holistic approach to water and ecosystem management. Future flood management planning and actions should proceed utilizing an IWM approach. Flood management planning based on IWM leads to better projects, reduces the need for more costly structural solutions, and

promotes multiple societal benefits, including public safety, environmental stewardship, and economic stability.

2. **Local, State, and federal agencies should work together to develop a roundtable to assess the applicability of all potential funding sources, propose new funding options, and identify needed changes to legislation by 2020.** The roundtable initially would review existing funding sources identified in the online resource catalog of flood management funding created by State and federal agencies, review other funding mechanisms, and make recommendations. The roundtable should also propose changes or alterations to local funding restrictions by pursuing exemptions to existing statutes for public safety. For example, changes to current laws (e.g., Proposition 218) could include reclassification of flood management agencies as exempted public safety utilities. The roundtable also could pursue establishment of regional assessment districts.

3. **By 2017, State and federal agencies should expand processes for developing, funding, and implementing flood management projects with an IWM approach in each region.** The use of IWM would promote and encourage incorporation of project components that achieve a broader range of objectives. Also, this would result in development of a common terminology for State and federal programs to help grantors and grant recipients understand IWM processes.

4. **By 2020, DWR should add compliance with best management practices and other statuary requirements for land use as a criterion for making flood management funding decisions as applicable to agency authorities.** Land use policies that keep new development out of floodplains and encourage compact, low-impact development can reduce costs of flood management projects.

5. **By 2017, working with the California Emergency Management Agency (CalEMA) and other State agencies, DWR should provide grant funding for increased coordination among flood responders, facility managers, planners, tribal entities, and representatives of State and federal resource agencies to improve flood emergency preparedness.** Coordination before a flood event improves emergency preparedness by identifying and reinforcing areas of expertise, available resources, and agreement about plans.

6. **State and federal agencies should establish more stable sources of funding to assist local and regional collaboration, including IRWM.**

7. **By 2020, the State should develop broad-based public funding to support recreational facility planning, construction, and O&M in flood protection projects as required by California Water Code Sections 12840-12842.**

## Develop and Disseminate Adequate Data and Tools

8. **DWR should ensure that guidelines, tools, and technical assistance for an IWM approach include best management practices for flood management by 2017.** Improved guidelines and technical assistance would provide tools and incentives for local implementation.

9. **DWR should provide technical assistance to local flood management agencies that encourage an IWM approach.** Improved guidelines and technical assistance would provide tools and incentives for local implementation.

10. **Local, State, and federal agencies should work together to develop methodologies and data to perform regional risk assessments across the state by 2020.** These efforts will provide flood management agencies at all levels with the data and tools necessary to establish and achieve appropriate levels of flood protection. Goals should be based on the number of lives and value of property at risk, degree of urbanization, number of critical facilities, type of flood, and level of acceptable risk for the region.

11. **DWR, academic institutions, USACE, U.S. Geological Survey (USGS), and the National Oceanic and Atmospheric Administration (NOAA) should build on studies currently underway to develop a climate change report by 2017.** The report would focus on climate change and its impacts on flood hydrology, concentrating on local extreme events instead of average precipitation and temperature changes. Such a report would be valuable because it would provide additional localized information to the State and would address water and flood-related issues that will be affected by climate change, understanding that flooding is impacted more by extreme events and that potential future impacts might be more severe.

12. **By 2017, DWR should catalog, provide, and promote online information and resources about flood risk, grants, and other related topics in a comprehensive statewide database.** DWR should develop a comprehensive statewide database on flood management that builds on and enhances existing efforts. The database should be accessible to flood management agencies and tribal entities. The database should include:

    A. Natural floodplain resources.

    B. Land use and watershed boundaries.

    C. Updated flood hazard areas.

    D. Floodplain mapping.

    E. Risk maps.

    F. Flood awareness information.

    G. Hydrologic, geomorphic, and climate change data and information.

    H. Relevant ecosystem information.

    I. Other relevant information.

    Easy access to data, case studies, budget information, and planning tools will improve local agency capabilities to identify opportunities for collaboration and integration. Additionally, online information resources should lead to an increase in the public's overall flood risk awareness.

13. **DWR should update the Flood Future Report by 2017 and every five years thereafter.** The update should cover:

    A. Risk assessment information.

    B. Regional planning efforts including prioritized projects.

    C. Flood readiness.

    D. Flood awareness initiatives.

    E. Land use decision-making.

    F. Agency alignment efforts in the context of IWM.

G. Flood-related funding needs.

H. Discussion of revisions to the recommendations to improve flood management.

14. **With input for local agencies, State and federal agencies should develop a methodology, including indicators and metrics, for evaluating regional or systemwide benefits by 2017.** The methodology should quantify benefits, such as ecosystem restoration, recreation and open space, water supply, groundwater recharge, sustainability, and community/social benefits.

15. **By 2017, local, State, and federal agencies should identify data and forecasting needs, including cost estimates, for emergency 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. Providing data and tools to improve system operations will improve overall management of natural and human-made flood systems.

16. **By 2017, DWR should release the next update of the Central Valley Flood Protection Plan.** Updates to the CVFPP will be prepared by DWR and its partner agencies (including USACE, the Central Valley Flood Protection Board, and local agencies) every five years, following adoption of the first CVFPP by the Central Valley Flood Protection Board in 2012.

## Improve Public and Policy-Maker Awareness and Understanding of Flood Risk

17. **By 2017, DWR should develop and disseminate educational outreach materials targeted for local governments and the public that clearly explain flood risks and measures that can reduce these risks.** Materials should include explanations of urban levels of flood protection, the limited role of FEMA 100-year floodplain maps, the role of the 2007 flood legislation, and types of actions for flood risk-reduction actions that are available to communities (nonstructural, natural floodplain function restoration, structural approaches, and emergency management).

18. **By 2017, DWR, in collaboration with local governments and organizations that represent flood management and land use professionals, should be developing land use planning principles and criteria that will help local planning agencies and decision-makers in conducting prudent land use planning.** These principles should be promoted as best management practices to increase prudent land use planning. These principles should promote preservation of existing floodplains and restoration of natural floodplain functions, where feasible. The planning principles should recognize unique differences of rural, suburban, and urban California. These best management practices should include definition of the philosophy to "minimize adverse environmental impact" for project planning.

19. **By 2017, local, State, and federal agencies and tribal entities should establish processes to leverage existing flood management awareness initiatives, data, and share outreach programs tools, templates, and other resource materials to local agencies.**

## Strengthen Agency Alignment

20. **Local, State, and federal agencies should pursue a regional permitting process to avoid limitations of compensatory mitigation, allow more landscape restoration opportunities, and facilitate more efficient permitting processes for project execution.**

21. **By 2017, local, State, and federal agencies should develop a plan to conduct regular 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 participation in training and functional exercises are a necessary part of disaster preparedness.

22. **By 2015, local, State, and federal agencies should work together to identify regional flood planning areas.** Flood management planning areas are needed throughout the state with boundaries that are systemwide, watershed-based where feasible, and consistent with existing federal and State agency boundaries, including existing IRWM funding areas and existing CWP planning areas. By organizing regional planning areas hydrologically, these areas would be better able to address issues that impact a united group of stakeholders. Also, such areas would enable the complex array of flood management agencies to begin working together to resolve common issues on a regional basis.

23. **By 2020, State and federal agencies should realign existing internal processes to support regional groups that undertake regional flood planning by addressing statutes that impede this realignment.** State and federal agencies can modify internal agency processes and programs that would assist local agencies in expediting project delivery and promoting multi-benefit projects. This effort should include the development of common terminology for State and federal programs, which would help agencies communicate the various aspects and benefits of multiple-objective projects, as well as remove the statutes that impede agency alignment.

24. **By 2017, resource agencies should collaborate to develop a permitting guidebook that includes a description of relevant permits, permit applications, and permitting guidance.** The guidance would include a description of the types of permits that are required for flood management projects and guidelines for when such permits are needed, explicit lists of what information permitting agencies require to issue these permits, and explanations of how and when to coordinate with regulatory agencies for project-specific and regional permitting approaches.

25. **By 2017, when issuing permits for flood facility maintenance or improvement projects, resource agencies should give priority to those projects where immediate action is needed and to those projects that provide the greatest long-term benefits to protect lives, property, and sensitive habitats.** Resource agencies should jointly develop regulatory guidance for issuing regional permits for flood control/stormwater conveyance maintenance or improvement activities, including consistent mitigation requirements for such projects. Resource agencies should develop guidance for expedited processes and/or appropriate exemptions, based on the California Environmental Quality Act, for emergency flood management activities and for flood control facility improvement projects that have minor wetland impacts.

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