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The Next Step in Central Valley Flood Management: Connecting Costs and Benefits

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Abstract

Historically, large expanses of California's low-lying Central Valley flooded nearly every winter. Over the past 150 years, individuals, communities, and state and national agencies have increasingly altered the landscape with levees, reservoirs, and bypasses to support agriculture and urban centers. The Central Valley's flood protection infrastructure and the institutions that manage flood risks have coevolved as risks and local needs have changed. The current state of flood management is in transition, as the recognition of a precarious disconnect between land-use decisions, flood liability, and flood infrastructure expenses unfolds. Substantial risks to public safety, the state's purse, and water supply are likely to be exacerbated by population growth and climate change. The paper identifies the strengths and weaknesses of the current flood management system, and explores several market and policy measures that might address the weaknesses of the system, especially the disconnection between flood management costs and benefits in California's Central Valley.

Introduction

California has always had floods, and always will (Kelley 1998). Flood management is a local, state, and national issue. Flood risks and damages affect all of California. The Central Valley is often a focus of flood management discussions because of its large watershed, aging infrastructure, and increasing floodplain urbanization. California also relies on controlling floods in the Delta to secure much of the state's urban and agricultural water supply. State responsibility and liability for flood damages also are concentrated in the Central Valley (Paterno vs State of California 2003). California's flood management system, with its knowledgeable people and extensive infrastructure, has facilitated much of California's economic development. However, while this system has performed well in the past, changing land-use, a growing population, changing climate, and poor maintenance of the aging infrastructure are increasing flood risks statewide. Land-use decisions are not always tied to public safety and economic risk. Lives, property, economic stability, and water supply are all at risk. The potential for loss of life and damages due to flooding is a function of both flood infrastructure (which determines how deep and how often an area floods) and land-use (which determines how many people and structures are at risk). Increasing growth in less protected areas raises flood risks. A frequent driver of Central Valley's damage risk is the disconnection between the responsibility for making land-use decisions and the responsibility for protecting public safety and preventing excessive flood damages.

With California's growing population, it would be unrealistic and unwise to end development in all areas at risk of flooding. With planning, development and flood management can occur such that threats to public safety, property, water supply, and the environment are reasonably balanced and allocated. The shorter the delay in addressing flood risks, the more options will be available, as well planned development has the potential to increase floodplain management options and decrease the costs of managing flood risks. The purpose of this paper is to educate and update notions of flood management to reflect the current understanding of Central Valley flood risks and the potential of innovative solutions. This paper's findings are based on readings

and discussions with over 30 knowledgeable individuals involved in California flood management.

Central Valley Flood Problems

In the California Central Valley, which includes the Sacramento River Valley and the San Joaquin River Valley, flood infrastructure includes levees, weirs, reservoirs, and bypasses. The historical approach to flood management in the Central Valley was to protect farmland and navigation by building levees on the banks of the rivers to increase the conveyance of mining debris through river channels (Kelley 1998). This restriction of the channel width has limited the storage capacity of Central Valley rivers, decreased their flood conveyance capacity and caused erosion (WEF 2005). These channel capacities were supplemented in the early 1900s by the system of bypasses and later by multipurpose reservoirs which include flood regulation (Kelley 1998). Channel capacities are greater in the Sacramento River Valley than in the San-Joaquin River Valley (Roos 2006), where precipitation is less and there are fewer urban areas. Increasing development behind Central Valley levees means that levees that were built over one hundred years ago on unknown foundations to protect agricultural land now protect more densely populated communities, which can suffer greater damages and loss of life when flooding occurs. Although levees, reservoirs, and debris basins can reduce peak flows in smaller events, when peak flows exceed their capacity, they cease to provide protection. When levees fail or reservoirs are filled, waters can rise quickly, and flooding can be sudden, fast moving, and deep. The impacts can be catastrophic, as was seen in New Orleans during hurricane Katrina.

The Delta, at the confluence of the Sacramento and the San Joaquin Rivers, poses unique risks for the entire state. The Delta conveys freshwater from the Sacramento River to the intakes for the State Water Project and the Central Valley Project, which provide much of the state's agricultural and drinking water supply. Massive levee failure in the Delta (particularly in drier months) would not only damage property and habitat, but would also cause seawater intrusion into the Delta, disrupting freshwater conveyance. Many of the Delta's over thousand miles of levees were constructed in the mid to late 1800's, often on weak peat soils (see Lund et al. (2007) for a detailed discussion of risks and potential outcomes in the Delta). The 2004 dry weather Jones Tract failure illustrates the unreliable condition of many Delta levees. Subsidence and sea level rise put increasing pressure on the Delta's levees, and the likelihood of major change due to floods or seismic activity is estimated at 2 in 3 by 2050 (Mount and Twiss 2005).

Flood Control vs. Flood Management

Notions of "flood control" have given way to the recognition that our ability to stop floods is finite. While floods cannot always be prevented, their threats to public safety, water supply, and the economy can be minimized by balancing traditional flood control with contingency planning. Historical notions of flood management focused on managing floodwaters, rather than managing flood risks. It is financially and physically impossible to provide complete protection from flooding. Because engineered systems, such as levees and reservoirs, can prevent frequent small flood events, providing some level of protection can lead to a false sense of security if communities do not know the limits of that protection. For example, in 1986, 1995, 1997, and 2006 communities in California narrowly avoided catastrophic flooding, yet in the Central Valley, development of new homes continues behind aging levees whose failure will result in deep flooding. Unplanned development of high risk land limits options for managing floods now and in the future, potentially increasing flood damages and management costs. Much of the

infrastructure in flood management (levees, reservoirs, etc) is designed to reduce or control peak flows. However, any flood control system will have some residual risk, the flood risk beyond that controlled by management. Because flood control capabilities are limited, sound flood management practices aim to effectively allocate resources to reduce economic and safety risks.

The Dutch system is a notable example of risk-based flood management (Rijkswaterstaat 2006 and Van Dantzig 1956). Catastrophic flooding in 1953 prompted this small coastal nation to provide high levels of flood protection. Using risk-based criteria, they weighed the costs and benefits of flood protection for each region. The Dutch provide from 1 in 1,250 year to 1 in 10,000 year nominal flood protection. Flood infrastructure is assessed by regional water boards every five years, using a procedure determined centrally by the Ministry to ensure consistency. The Ministry also sets safety standards and invests in new protection, while regional agencies assess taxes and maintain infrastructure. The Dutch Directorate for Public Works and Water Management describes the consideration of both equity and efficiency in determining flood protection levels. Providing a minimum reliability of protection equitably protect all lives, while protecting higher risk urban areas at a higher level can more efficiently prevent large scale loss of life. Figure 1 demonstrates the concept of risk-based cost benefit analysis used by the Dutch. Such calculations can be used as an aid for determining a desirable level of flood protection. Other considerations include as equity and minimum public safety standards. Recently, Dutch engineers have also developed reliability based models, which account for multiple modes of levee failure (Steenbergen et al. 2004).

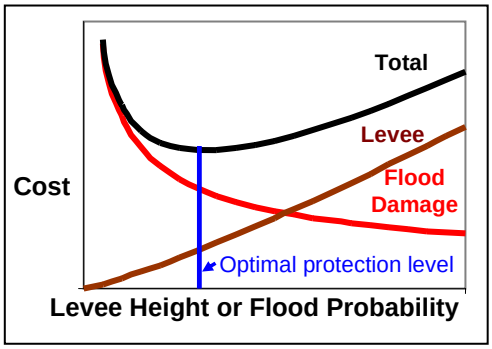

Figure 4- Dutch concept of cost-benefit analysis for flood protection (modified from Rijkswaterstaat (2006)).

Currently, many areas of Central Valley do not have 1 in 100 year protection. Given the relatively small channels and large at risk area, Californians might not find the resources to equal Dutch protection (note that there are some differences between Dutch and United States' flood frequency estimation methods, so they are not directly comparable). However, the Dutch lessons of equity, efficiency, and risk-based calculation can be helpful when considering flood protection standards and policies in California. It may be desirable to aim for a higher minimum protection level for urban areas than the current protection level of 1 in 100 year. This could either take the form of area-wide standards, or tailored flood protection levels that require builders to calculate and conform to an appropriate level of risk given the type and location of development. Builders could be provided with a code to guide these calculations, similar to structural building codes that vary with local earthquake and storm conditions.

Flood risks are complex and changing. Flood management policies can be more effective if they account for interdependencies of the entire system as well as changes in land-use, climate, and

infrastructure. Reducing flooding in one place can increase flooding elsewhere. A portfolio of structural and non-structural actions can be an effective and efficient approach to flood management. Flood damages are a function of both flood infrastructure and land-use, and both are important for understanding how to focus flood protection efforts. Unlike traditional methods of flood control, the goal of flood management is to minimize loss of life and net damages through both structural and nonstructural actions. Structural approaches focus on flood control infrastructure to keep floodwaters away from people (e.g. reservoirs, debris basins, levees, weirs, canals, and bypasses), while non-structural approaches apply management methods (such as floodplain management, building codes, education, evacuation, flood insurance, and emergency response) to minimize the damage potential of floods. Protecting existing development and encouraging well planned development are both important for protecting public safety and reducing costs.

Flood risks change with technology, climate, settlement patterns, and hydrology. Changing climate conditions and population growth will increase flood risks. Climate change in California may increase storm intensity, sea level rise, and reduce the snowpack, potentially increasing inland and coastal flood risks, as well as challenging reservoir operators to accommodate both an increase in flood storage needs and a decrease in natural water supply storage. Climate change may also affect several other determinants of flood risk, including shifting vegetation, increasing wildfires, declining forest productivity, and shrinking beaches (Luers at al. 2006). In addition, California's population is expected to grow from 35 million today to 55 million by 2050, further increasing development pressures in at-risk areas. New technology can somewhat decrease flood risks by improving management and infrastructure. For example, reservoir upgrades and improved reservoir operations and weather forecasting can reduce peak flows by allowing reservoir operators to make early releases, and capture more of the peak flow in the reservoir. However, even with early releases, there are limits to the capacity of reservoirs to reduce floods.

In conjunction with new technologies and infrastructure maintenance and upgrades, well planned development and floodplain management can reduce growing flood risks by minimizing increases in peak flows due to runoff from new development, increasing the effectiveness of new and existing flood protection infrastructure, and putting fewer new homes and businesses in high risk areas.

Strengths and weaknesses of flood management system

The following are strengths of the flood management in the Central Valley:

a) Sacramento River bypass system: Foresight in the late 1800's led to the construction of leveed lowland floodways in the 1910's (Kelley 1998), which carry over 80 percent of design flood flows in some areas of the Sacramento River Valley (Roos 2006). The bypasses and weirs mimic the river's natural ability to greatly expand during high flows, lowering water levels in the main channel. Additionally, many sections of the bypass system can be used for compatible purposes of farming, recreation, and environmental habitat.

b) Knowledgeable people and past performance: The existing flood management system has provided flood protection to many areas of California, facilitating economic growth over the past 150 years. However, changes in land use, climate, and aging infrastructure will increase risks and challenges for flood managers. Despite current weaknesses in the system, given

adequate resources and effective policies, California can adapt the current system to reduce flood risks.

c) Improved weather forecasting: As scientists' ability to forecast weather and snowmelt has improved, so has their ability to operate reservoirs to reduce peak flows and alert at-risk residents and emergency responders. In the lower Sacramento and San-Joaquin Rivers, National Weather Service (NWS) and California Department of Water Resources (DWR) can issue guidance forecasts for several days in advance, although accuracy is limited.

d) Strong local leadership: Many communities in California have taken a proactive role in managing their flood risk not only by maintaining their existing infrastructure, but also by planning for the future and adapting to changes in their community. For example, the community of Napa has brought local business and environmental interests together with the U.S. Army Corps of Engineers to plan a new flood project which will incorporate habitat, an aesthetically pleasing riverfront, and flood control. Roseville and the Sacramento Area Flood Control Association have improved urban flood protection levels.

Despite the strengths of California's flood management system, changing conditions (including development of at risk areas, climate change, and aging infrastructure) can increase the risks of flood damage in California. Several problems exist:

a) Disconnect between land use and protection levels: Many communities in California face increased risks due to aging infrastructure and development in flood-prone areas. Individuals, communities, the State, and the Nation all pay for increasing risks. However, the local share of these costs is not always proportional to the local role in flood management decisions, especially in the Central Valley. Furthermore, there is a strong incentive for communities to grow to improve their economy and increase tax revenues. The separation between agencies responsible for growth and those responsible for safety can lead to unbalanced decision making, especially when faced of flood risks, which are not always well understood or appreciated. Figure 2 illustrates the weak relationship between flood management and liability that can reinforce incentives for floodplain development. Note that due to a land-use liability disconnect, the state loses money and locals gain money as floodplains are developed and flood risks increase.

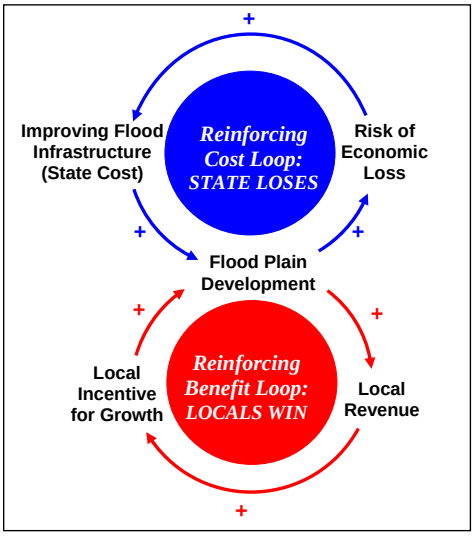

Figure 5- State and local roles in California flood management and risk

The state's role in flood management (including infrastructure maintenance and land-use decisions) is limited. Throughout the state, DWR provides disaster relief, subventions to reimburse local flood agencies for work, and some funds for mapping. DWR is most active in the Central Valley, where they are the local sponsor for Federal project levees. However, the state has turned over much of the responsibility for maintaining project levees to local reclamation districts, retaining their authority to step in (and assess landowners) if the district fails to adequately maintain their levees. Many districts, especially in predominantly agricultural areas, struggle to obtain revenue to maintain their levees. While the State Reclamation Board has the power to regulate development in flood prone areas of the Central Valley, they rarely exercise this authority, and most decisions are made by city and county officials.

Flood damages in communities throughout the state increase the economic burden on all Californian and American taxpayers, as state and federal disaster assistance programs (including Federal Emergency Management Agency's (FEMA) National Flood Insurance Program) are subsidized by taxpayer dollars. In the Central Valley, the situation is especially problematic, as state government bears much of the liability for flood damages to project levees under the recent *Paterno* decision. In 2003, in *Paterno vs. California*, the state was held liable for flooding in Yuba County in 1986 for not having a reasonable plan for protecting flooded lands, which amounted to taking the lands (Paterno vs. California 2003). In the Central Valley, project levees are those that were adopted and improved upon or built by the US Army Corps of Engineers. Many of these were turned over to the state for maintenance. The state often passes this maintenance authority on to local districts, though the state retains oversight. It is estimated that Central Valley project levees protect $47 billion of land and structure, as well as half a million people (DWR 2005 and Paterno vs. California 2003). In the Delta the state's water supply is at risk, and local reclamation districts do not have the tax base to adequately maintain levees. Additionally, the economy is interdependent, and economic losses in one area can affect other areas. For example, the estimated cost of damages from the 1997 floods is $2 Billion, while the estimated total cost to the state, including indirect economic costs is $5 Billion (DWR 2002).

Local agencies gain tax revenue from new development (Because property tax on existing housing does not grow with property value (under Proposition 13) and it is difficult muster the required 2/3 vote to approve a tax increase (under Propositions 13 and 218), local agencies sometimes look to new development to increase tax revenue (Hill 2003 and LAO 2006)), but local agencies are not liable for failure of project levees. Thus, there is less incentive for local agencies to cautiously plan development in at-risk areas, especially those that are not designated by FEMA as within the 100-year floodplain. While further development is one approach to raising funds to protect existing development, the time lag time between new development and infrastructure improvements leaves a window of increased risk. Also, some new developments occur in areas that are prohibitively difficult to protect and place more people and property at risk of deep or sudden flooding.

b) Lack of understanding of risks: Poor understanding of flood risks and liabilities by decisions makers and the public is another impediment to sound flood management. Many Californians are unaware of their own flood risks. Most homeowners are not notified of their risks if they are outside of FEMA's 100-year floodplain, and even residents of the 100-year floodplain may not understand the severity of their risks. This is coupled with a lack of awareness of the state and national taxpayer burden in flood and disaster assistance programs.

The Federal Emergency Management Agency's (FEMA's) Federal Insurance Rate Maps (FIRMs) simplify flood risks and are prone to error, contributing to poor understanding of risks. Although FEMA's 100-year floodplain maps were developed for flood insurance purposes, they are used to plan new development and disaster response should flooding occur. However, their accuracy is limited by outdated assumptions used to calculate water levels (such as changing land-use or climate or a longer period of recorded weather), incorrect assumptions (such as assuming all project levees provide 100-year protection), and lack of information. When FEMA was creating Flood Insurance Rate Maps (FIRMs), the US Army Corps of Engineers certified all project levees as providing 100-year protection. However, many levees in California (especially in the Central Valley) were built over one hundred years ago on questionable foundations, such as sand or peat. These soil types allow underseepage, erosion, and subsidence. This problem has recently come to light, especially after the dry weather failure of the Jones Tract levee in 2004. FEMA is in the process of requiring communities to document the integrity of their levees to certify 100-year protection levels. 100-year floodplain maps show areas where the chance of flooding exceeds 1% per year, but show no detail about the extent of less frequent floods. Homes just outside of the 100 year floodplain may have up to a 26% chance of flooding in the lifetime of a 30-year mortgage (The probability of a flood equal to or larger than a 1-percent chance event (100-year flood) during a 30-year period (mortgage lifetime) is 26 percent, or 1- $(1-0.01)^{30}$). Additionally, the 100-year floodplain does not clearly convey the risks posed by levees. Levees can fail before they are overtopped, but the chance of this happening is not usually incorporated in FEMA flood estimates.

c) Lack of long-term comprehensive program: California flood management goals are often short-term and funding of flood management at the state level fluctuates with California's political and economic climate. Irregular funding means that it is difficult to consistently provide emergency and flood fight training, retain expertise, maintain flood control infrastructure, and engage in consistent long term planning efforts, including mapping, infrastructure planning, and floodplain management. In addition to irregular state funding, many local flood districts cannot raise adequate funds. Taxpayers would be better served by regular funding of flood management, so that risks do not escalate in the years between floods and funding.

Recent local and national events and legal liability rulings have brought California's flood risks into the spotlight. Last November, California voters passed two bonds (Propositions 1E and 84) that together provide $4.9 billion for flood management. Flood management funding has varied greatly in recent years. While the bonds provide funds to update flood infrastructure (including subventions and improvements), they also provide some funds for repairs and mapping, which are ongoing expenses that will continue to require funding after bond funds run out. Regular funding of ongoing costs can potentially reduce the total cost to taxpayers. So while bonds can support infrastructure updates, they do not diminish the need for long-term funding for ongoing maintenance, mapping, and planning. Furthermore, although the bonds provide immediate funds to improve infrastructure, they do not address the chronic problem of why flood infrastructure is no longer sufficient. In the current political climate, bonds may be the most politically feasible way to provide substantial funds for flood infrastructure improvements. How those funds are spent will determine how helpful they are. Well planned expenditures in conjunction with smart flood management policies can improve the efficacy of bond funding. Future legislative sessions provide continued opportunities to revisit flood management policies, and it may be easier to

reach agreement shortly after high profile flooding, such as Katrina and the winter 2006 high water in the Central Valley, while political will and attention is high.

Currently, much attention of flood management is focused on keeping up with historical changes, such as urbanization and aging infrastructure. California communities face continued changing conditions, most notably urbanization and climate change, which increase the risk and frequency of floods. It is essential that planners engage in long-term floodplain management to anticipate and respond to climatic and population changes in California.

Recommendations

Improving infrastructure alone will not eliminate flood risks. Residents who are aware of flood risks can plan for emergencies, buy insurance, and make informed home purchases. Emergency responders, flood managers, and policymakers with access to up-to-date, relevant information can make more informed policy and planning decisions. Comprehensive flood mapping, including mapping beyond the 100-year floodplain, mapping inundation depths (especially in areas at risk of deep flooding), and maps of future risks based on projected land use and climate change can better inform decision-makers from households, to local agencies, to regional and State agencies and policy-makers. The State could provide DWR with the resources to work with communities to create and maintain comprehensive flood maps, or they could give communities incentives, resources, and oversight to create and maintain comprehensive flood maps. These maps should also meet FEMA mapping objectives. Counties could notify residents of comprehensive flood risks as well as the availability of flood insurance. All Californians could be made aware of statewide flood risks, including state liability for flood damages, threats to water supply, and large scale social and economic impacts of flooding, so that they can make informed decisions about long-term flood planning and funding.

The state could take the lead in formulating a comprehensive plan for California flood management. Assessment districts could assess beneficiaries of flood management, including at-risk communities and residents, new developments in at-risk areas (which might deter building in areas that cannot be reasonably protected), and state residents who benefit from water supply, environmental and recreational improvements, and reduced liability. Funds could be distributed for local and regional flood management efforts. Local districts could maintain much of their authority, and State oversight could include incentives for regional collaboration, smart flood management, and land-use planning. Either DWR, the State Board of Reclamation, or an assessment district could require and approve local flood management and floodplain management plans and monitor implementation. DWR could provide technical resources and advice to local districts. The state could create incentives for regional collaboration of local, state, and federal agencies, and stakeholders for comprehensive planning, infrastructure maintenance and improvements, new projects, floodplain management, and disaster response.

In regions protected by state owned project levees, the state of California could allow communities to choose either to invite additional state or regional participation in flood management and land-use planning, or agree to bear more liability for flood damages. This could create an incentive to better align of flood authority and responsibility. Because it is not possible to protect all at-risk areas to 200-yr (or higher) levels, communities could establish flood protection boundaries. This boundary could consider housing and development pressures as well as the feasibility of flood protection. In designated at-risk rural areas, new development might be curtailed, and flood-proofing and voluntary relocation of existing structures could be

considered. DWR or assessment districts could establish minimum urban and rural protection levels, such as at least 200-year (or 500-year) urban protection and an upgrade of rural infrastructure to design protection levels or other minimum standards. As with earthquakes, State oversight could monitor establishment of boundaries and implementation of standards or building codes by local agencies. Where urban areas benefit from lower water levels due to rural flooding, regional flood planning agencies could create urban-rural partnerships to compensate rural communities as was done with the establishment of the Sacramento Valley flood bypass system. In areas where homes are already built and cannot be adequately protected, precautions should be taken to minimize damages. DWR and FEMA could provide resources for flood-proofing and voluntary relocation and DWR or another state agency could require local emergency (notification, flood fight, and evacuation) plans. Planners could consider stricter building requirements in areas at risk of deep flooding, including building two-story homes and placing critical infrastructure (such as hospitals, shelters, schools, and evacuation routes) above high water.

Conclusions

A balance of state and local funding of flood management can improve accountability and use of resources. State and local governments and at-risk residents all bear flood damages and receive benefits from flood protection. Requiring some local responsibility provides an incentive for responsible local decisions that can reduce flood risks, and supplementing local resources with state funds and knowledge can increase the effectiveness of flood management. In addition, multi-objective approaches to flood management and involving federal agencies with flood management responsibilities can potentially tap additional funding sources. While local agencies, organizations, and individuals know their needs and capabilities best, state government can guide and support at-risk communities to help protect the safety of at risk residents, water supply, the environment, and the economy. The State, counties, or regional flood management projects are available to address the extra-local flood effects of local activities.

A variety of combinations of structural improvements, multi-objective projects, and smarter development in at-risk areas can uniquely address each community's needs. Education, regular funding, comprehensive planning, and coordinated governance will provide more consistent management of flood risks. Proactive planning, which may not occur quickly, requires sustained funding, education, improved understanding of risks, innovative approaches to management, and incentives for cooperation and collaboration among different interests.

California can pay for flood management or it can pay more for mismanagement. No single solution will "fix" California's flood problems. A combination of approaches is called for, and we recommend several areas of action to address multiple weaknesses in the current flood management system:

1- Increase Risk Awareness and Information through improved mapping, notification, and education of the public.
2- Comprehensive Flood Policy and Planning, including formulating legislation, sustained funding mechanisms, and improving coordination between state and local agencies and stakeholders.
3- Coordinate Land-Use and Public Safety by sharing liability for flood damages, establishing urban and rural boundaries and protection standards, compensating rural areas for urban benefits, and planning for contingencies.

4- Explore Promising Solutions for improving flood infrastructure, widening floodways, incorporating multiple benefits, and researching new approaches and technologies for flood management.

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References

- DWR. 2002. *Final Recommendations Report*, The Department of Water Resources (DWR) Floodplain Management Task Force, December 2002.
- DWR. 2005. Flood *Warnings: Responding to California's Flood Crisis*. State of California, The Resources Agency Department of Water Resources, January 2005.
- Hill, J. 2003. *Debate over Prop. 13 still rages*. Sacramento Bee. June 1 2003.
- Kelley R. 1998. *Battling the Inland Sea: Floods, Public Policy, and the Sacramento Valley, 1850 - 1986*. University of California Press, Berkeley.
- LAO 2006. Legislative Analyst's Office: Understanding Proposition 218.
- Luers, A., Cayan D., Franco, G., Hanemann, M., Croes, B. 2006. *Our Changing Climate: Assessing the Risks to California.* Summary Report, California Climate Change Center. CEC-500-2006-077. July 2006.
- Lund, J., Hanak, E., Fleenor, W., Howitt, R., Mount J., Moyle, P. 2007. *Envisoning Futures for the Sacramento-San Joaquin Delta*. Public Policy Institute of California, San Francisco, CA.
- Mount, J. F. and R. Twiss. 2005. Subsidence, Sea Level Rise, Seismicity in the Sacramento-San Joaquin Delta: *San Francisco Estuary and Watershed Science*, v. 3, Article 5.
- Rijkswaterstaat. 2006. *Risk Based Decision Framework for Flood Protection* (DRAFT). Ministerie van Verkeer en Waterstaat, Rijkswaterstaat. July 31, 2006.
- Roos, M. 2006. Flood Management Practice in Northern California: *Irrigation and Drainage*, 55: S93-99, 2006.
- Steenbergen, H.M.G.M., Lassing, B.L., Vrouwenvelder, A.C.W.M., Waarts, P.H., 2004. *Reliability analysis of flood defense systems*. Heron, 49(1).
- Paterno vs. State of California. 2003. Court of Appeal of the State of California, Third Appellate District. Filed 11/26/03.
- Van Dantzig, D. 1956. Economic decision problems for flood prevention: *Econometrica*. 24: 276-287.
- WEF 2005. *Layperson's Guide to Flood Management*, Water Education Foundation, Sacramento, CA.

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