Flood Hazards in the Central Valley of California

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This special issue of *Natural Hazards Review* is devoted to flood hazards in the Central Valley of California. The Central Valley is a large, north–south-striking trough that comprises the Sacramento Valley to the north and the San Joaquin Valley to the south. These two large valleys are separated by the Sacramento–San Joaquin Delta (the delta), the largest inland delta in the United States. This introduction provides a description of flood hazard policies, how they apply in the Central Valley, recent structural and legislative changes that influence flood hazards and policy in the region, and an outline of the six papers published in this issue. The papers cover a variety of topics ranging from physical to social characteristics and processes. Collectively, they describe severe flood hazards in the region that will require considerable attention to avoid major flood disasters.

Background

Accelerating flood damages and losses of life in the United States from the 1970s to the 1990s have been attributed to population growth, development, climate change, and federal policies. Although all these processes are involved, the empirical basis for measuring their relative importance and linking them together is constrained by a lack of flood damage data and data-collection methods (Downton et al. 2005; Downton and Pielke 2005). In spite of flood damage data limitations, it has been well documented that flood control methods have been effective in reducing flood losses, but that flood-control-only policies are fraught with shortcomings (Galloway 1995). Consequently, floodplain management has grown in importance nationwide and has reduced flood impacts through a decreased reliance on structural flood-control approaches, increased awareness of the potential for behavioral modification, and incorporation of economic disincentives to intensive floodplain development [e.g., ASFPM 2000, 2007].

Level of Flood Protection in the Central Valley: Real versus Perceived

Comparisons are often made between flood hazards in the Sacramento and Mississippi basins. One commonality between St. Louis, New Orleans, and Sacramento is urbanization of low-lying areas and reliance on levees for protection. Mississippi River floods arrive slowly, however, and can be forecast months in advance; for example, the 1993 flood took three months to crest at St. Louis. The New Orleans flood developed rapidly but was essentially a coastal phenomenon, as Katrina came from the sea. Hydrologic and geomorphic characteristics of the Central Valley combine to generate highly variable and rapidly responding flow regimes in the valleys below. The flood basins are topographically low, hydrologic variability is high, the flood-control system has limited conveyance capacity, and extreme floods are inevitable.

Given the geomorphic and hydrologic nature of the Central Valley, no practical flood-control system can eliminate flood risks entirely. Providing complete protection from flooding through the use of dams, levees, and bypasses is not feasible. The modern levee system in the lower Sacramento Valley extends approximately 9,600 km (6,000 m), but only one-third of this length of levees meet federal standards (O'Neill 2006). The San Joaquin Valley and Delta also have extensive levee systems. Climate-change scenarios predict increasing flood variability, larger winter floods, and decreased summer and fall water yields. Growing water demands and water-resources conflicts will compete with reservoir flood storage and challenge the sustainability of present flood-control reservoir-operating policies.

The Sacramento Valley flood-control system greatly reduced the frequency and area of inundation in low-lying basins of the valley. The system was largely successful in achieving the initial goals of reducing inundation frequencies while maintaining multipurpose functions for water supply, power production, and recreation; however, public perception of the level of flood protection provided by this system has become unrealistic. The Sacramento Valley flood-control plan was originally intended to be able to convey a flood magnitude equivalent to the 1907 or 1909 floods on the Sacramento River. Floods greater than these design floods cause flooding in some areas. Since land use in most low-lying areas behind the levees was agricultural at the time of system design, occasional levee failures did not cause extreme damage or impose severely on public safety.

Recent urban residential development has fundamentally changed the situation. New housing developments have sprung up behind levees in topographically low positions of the Central Valley. For example, almost 12,000 homes were proposed for the Plumas Lake area (*Marysville Appeal-Democrat*, March 20, 2004), which is one of the topographically lowest positions along the lower Feather River. As of June 30, 2007, more than 1,600 building permits had been issued for developments in the Three Rivers Levee Improvement Authority (TRLIA) area, with 258 building permits issued between January and June 30, 2007 (TRLIA 2007a).

Floodplain development in the Central Valley has been partly in response to the success of the flood-control system in reducing flood frequencies. This pattern of floodplain development following structural flood control has been recognized elsewhere (White 1964). Development has also been promoted by rapid population growth and extreme valuations of residential property values elsewhere in the state. With urban development came a false sense of confidence in the flood-control system and increasingly unrealistic expectations for the level of flood protection.

Several developments have changed the way that flood hazards are perceived in the Central Valley. First, Hurricane Katrina revealed once again the high stakes involved in flood hazards and the very real political, economic, and public safety consequences of lack of preparation. Katrina intensified local interest and activities concerned with understanding and reducing flood risks. A second factor that received attention by the local media is the rapid, ongoing urban development in lowland areas. Third, a realization emerged among many scientists that global climate change is already occurring in the region and will have substantial impacts on flow variability and flood risks.

In short, both social vulnerability and flood risks have increased dramatically in the region by the convergence of a number of processes. All these developments are key to understanding the changing nature of flood hazards in the Central Valley. Collectively, they threaten the ability of the existing flood-control system to provide reliable protection from catastrophic flooding. Last, the potential for levee failures caused by seismic activity has become a larger threat based on the forecasting of a 63% chance of an earthquake of magnitude 6.7 in the San Francisco Bay region in the next 30 years (USGS 2008).

The condition of existing levees came into question before Katrina. In 2003, the U.S. Army Corps of Engineers investigated flood-control levees along the lower Bear River and found that portions of them lacked the freeboard required by federal standards. Affected areas in Yuba County, including portions of the Plumas Lake housing development, were mapped in the special flood hazard area by the Federal Emergency Management Agency (FEMA). This change in designation threatened to subject many local landowners to floodplain regulations, increases in flood insurance rates, or constraints on building permits.

Subsequently, the TRLIA was created in 2004 by Yuba County and Reclamation District 784 to develop levee-improvement plans for the lower Feather, Yuba, and Bear rivers. This prompted two major levee setback projects. A 3.2-km length of levees near the mouth of the Bear River was set back, and a 9.6-km stretch of levees on the east bank of the Feather River above Star Bend is under way. Funding for these projects was expected to exceed $360 million, which was being raised through a combination of a FEMA Federal Emergency Management Grant, state funds, county funds, and contributions from developers (TRLIA 2007b).

As of July 2007, $73 million of an expected $135 million in contributions from developers had been raised that will ultimately be repaid with interest through a series of bond sales and impact fees (TRLIA 2007b). The policy of funding levee improvements with contributions from developers in floodprone lands should be discouraged. If we are to learn from the past, levee improvement programs should be coupled with disincentives to economically irrational development behind levees, and project evaluations need to be objective.

Papers in This Special Issue

The first three papers in this issue are concerned with hydrogeomorphic and physiographic characteristics of the Central Valley. Singer et al., "Status of the lower Sacramento Valley flood-control system within the context of its natural geomorphic setting," describe the natural hydrology and geomorphology of the Sacramento Valley and the flood weir and bypass system. They begin with a brief explanation of interactions between valley-scale tectonics, geomorphology, and flood hydrology and how these natural processes influence the modern flood-bypass system. They point out that most discussions of flood hazards and flood control policies in the lower Sacramento Valley have concentrated on the dams and levee system. Relatively little attention has been paid to the condition and maintenance of the weir and bypass system that conveys most of the discharge of extreme floods and is far more important to controlling flood hazards in the lower valley. They review reports of sediment delivery, storage, and excavation and document recent sedimentation within the bypasses using isotopic dating (^{210}Pb). Sedimentation of the flood bypasses threatens to impair flood conveyance and could be critical to flood hazards in the region.

Florsheim et al. "Geomorphic influence on flood hazards in a lowland fluvial-tidal transitional area, Central Valley, California," describe the lowland geomorphology and interactions with levees in the northeast delta and lower Cosumnes and Mokelumne rivers. Flood hydrology in the delta is dominated by large and rapid flow variations driven by external climatic forcings. Distributary channels are strongly influenced by tidal fluctuations and subsidence and have been prone to frequent avulsions over geologic time. Before flood control, natural levees protected delta islands from tidal inundation, but not from frequent fluvial flooding. Construction of extensive high levees provided a degree of protection from frequent river flooding, but levee failures periodically result in sudden and extensive flooding.

An analysis of flood hazards and geomorphic changes was conducted using historical maps, aerial photographs, U.S. Geological Survey stream-flow gauge data, and LiDAR topography. The authors find that flood hazards in the delta are increased by progressive subsidence driven largely by oxidation of organic soils, e.g., recent subsidence in the McCormack Williamson Tract. They call for sustainable, landscape-scale flood management that integrates fluvial and tidal process with habitat and land-use maintenance while anticipating sea-level rise and enlarged peak flood magnitudes. Moreover, they recommend removal of existing developments and a moratorium on new construction on these lands.

James and Singer, "Development of the lower Sacramento flood-control system: Historical perspective," describe the historical evolution of the flood-control system in the Sacramento Valley and how it was influenced by the need to control nineteenth century hydraulic mining sediment. Rapid channel aggradation by mining sediment in the Sacramento Valley exacerbated natural flood hazards and led to an early reliance on an extensive system of levees. Early brush dams and other structures in the lower Yuba and Bear rivers failed, undermined confidence in the ability of the dam technology of the late 1800s and first decade of the twentieth century to provide sedimentation and flood control. Initial attempts to contain the Sacramento River in a single channel—modeled largely on flood-control works along the lower Mississippi River—repeatedly failed, ultimately leading to the development of the present flood-bypass system in the early twentieth century (Kelley 1989). The bypass system to some degree mimics the natural system of limited channel conveyance during floods and large proportions of flood flows carried in an overbank channel system.

The remaining three papers cover interactions between the physical system and human impacts. Burton and Cutter, "Levee failures and social vulnerability in the Sacramento–San Joaquin delta area, California," examine the likely exposure of delta residents to catastrophic flooding. Using a modeling approach to simulate breaches in levees, they demonstrate the spatial variability in the likely extent of the flooding. When integrated with measures of social vulnerability, Burton and Cutter forcefully demonstrate the disproportionate impact of potentially catastrophic levee failures on populations that are least able to prepare for and respond to them. These pockets of high social vulnerability and high flood hazard exposure warrant management concern and illustrate that a one-size-fits-all mitigation strategy does not adequately address the social and physical factors that interact to produce the hazard.

Montz and Tobin, “Livin’ large with Levees: Lessons learned and lost,” provide a case study of Yuba County, California, which is experiencing extensive development pressures in floodprone areas. In a discussion of the general nature of levee protection, they note that levee failures or overtopping cause approximately one-third of the flood disasters in the United States, that levees tend to pass flood problems downstream, and that levee construction often promotes floodplain development.

Montz and Tobin ask whether or not local communities respond to levee-failure disasters elsewhere and if 3 of the 25 recommendations made by the Association of State Floodplain Managers (ASFPM 2007) are being considered in the context of flood control in Yuba County. They outline the extensive history of flooding in Yuba County on the Yuba, Bear, and Feather rivers and point out that ongoing development of floodprone lands indicates that lessons have not been learned. Given the county’s extensive experience with flooding due to levee breaks, the county has developed a risk-management strategy that has aggressively addressed levee improvements. Their strategy does not include a comprehensive approach to flood hazard management, however, and should have greater emphasis on nonstructural approaches such as mandatory flood insurance for residents in levee-protected areas.

Finally, Fridirici, “Floods of people: new residential development into flood-prone areas in San Joaquin county, California,” examines development pressures and the rapid urbanization of southern San Joaquin County. Urban residential development is examined from the perspective of real estate market pressures, transportation, and the explosion of housing prices in the Bay Area of San Francisco. As the fifth fastest growing county in the state, the county houses an estimated 60,000 commuters who cannot afford to live in the Bay area, where median home prices have reached $748,000. Consequently, the housing market in the county distorts perceptions of flood hazards. People are preoccupied with housing prices, local governments are reticent for fear of depressing housing values, and government agencies experience political pressure to ignore the issue. Interestingly, under these circumstances, residents may not associate rivers and levees with flood hazards but see them as designed suburban landscape elements that are promoted as open space or recreational features. As the mortgage crisis intensifies in the region, much housing is now for sale or in foreclosure. The depressed housing market may be an opportunity to instill much-needed flood-hazard awareness and preparedness programs.

Conclusion

The Sacramento Valley flood-control system and additional flood-control measures in the Delta and San Joaquin Valley reduced the extent of flooding and constrained frequent flooding to designated low-lying areas of the Central Valley. While the flood-control system has largely performed as planned, levees cannot eliminate flooding behind levees entirely. Many low areas are at risk, and flooding may be catastrophic where extensive development has occurred. Both flood vulnerability and expectations for the level of protection from the flood-control system have risen. Rapid construction of housing developments in low-lying lands has raised vulnerability, while increasing hydrologic variability has decreased the return period of high-magnitude discharges. In addition, questions of levee reliability have been raised and maintenance of the existing system has proved to be expensive. For example, ongoing repairs along the lower Feather and Bear rivers are budgeted at over $360 billion dollars, which has resulted in reliance on contributions from developers to initiate levee improvements.

Historically, Central Valley flood-hazard management measures have been overwhelmingly structural. Flood-avoidance policies, postflood contingency planning, mitigation, and other nonstructural measures have been weak in the valley, and few disincentives to development behind levees are in place. It has been shown in the Central Valley and elsewhere that structural flood-control methods alone do not provide adequate flood-hazard mitigation; sustainable planning measures are needed that constrain development in floodprone lands in the valley. Perhaps the time is here to rethink current approaches to flood-hazard management in the region and challenge the complacency of residents mired in the perception of safety caused by the so-called “levee effect.”

References

Association of State Floodplain Managers (ASFPM). (2000). “National flood programs in review–2000. Summary.” Assnociation of State Flood Plain Managers (ASFPM), Madison, Wis., ⟨http://www.floods.org/PDF/2000-fpr.pdf⟩ (accessed June 11, 2008).

Association of State Floodplain Managers (ASFPM). (2007). “Background reading for the Gilbert F. White National Flood Policy Forum, 2007 Assembly, Floodplain Management 2050.” George Washington University, Washington, D.C., ⟨http://www.floods.org/Foundation/Files/2007_GFW_Forum_Background_Reading.pdf⟩ (accessed June 11, 2008).

Downton, M., Miller, J. Z. B., and Pielke , R. A., Jr. (2005). “Reanalysis of U.S. National Weather Service Flood Loss Database.” *Nat. Hazards Rev.*, 6(1), 13–22.

Downton, M., and Pielke Jr., R. A. (2005). “How accurate are disaster loss data? The case of U.S. flood damage.” *Natural Hazards*, 35(2), 211–228.

Galloway, G. E. (1995). “New directions in floodplain management.” *Water Resour. Bull.*, 31(3), 351–357.

Kelley, R. (1989). *Battling the inland sea: American political culture, public policy, and the Sacramento Valley, 1850–1986*, Univ. Calif. Press, Berkeley, Calif.

O’Neill, K. M. (2006). “Levee troubles: The cost of making the Sacramento Valley into an agricultural giant.” *Sacramento Hist. J.*, 1(1–4), 73–104.

Three Rivers Levee Improvement Authority (TRLIA). (2007a). “Three Rivers Levee Improvement Authority Project Status Report, July 6, 2007.” ⟨http://www.trlia.org/⟩ (May 11, 2008).

Three Rivers Levee Improvement Authority (TRLIA). (2007b). “Three Rivers Levee Improvement Authority2007/08 budget, approved July 17, 2007.” ⟨http://www.trlia.org/⟩ (May 11, 2008).

U.S. Geological Survey. (2008). “Forecasting California’s earthquakes—What can we expect in the next 30 years?” ⟨http://pubs.usgs.gov/fs/2008/3027/fs2008-3027.pdf⟩.

White, G. F. (1964). “Strategic aspects of urban floodplain occupance.” *J. Hydr. Div.*, 86(HY2), 89–102 (Reprinted 1986 in Kates, R. W. and I. Burton, Eds., *Geography, Resources, and Environment*, Vol. I, selected writings of Gilbert F. White, Chicago, Univ. Chicago Press).