Item No. 14-1

Supplemental Material

For

City of Sacramento

City Council
Housing Authority
Redevelopment Agency
Economic Development Commission
Sacramento City Financing Authority

Agenda Packet

Submitted: January 25, 2008

For the Meeting of: January 29, 2008

☒ Additional Material
☑ Revised Material

Subject: Greenbriar Correspondence

Staff received the following items for the Greenbriar project from James Pachl:

- An e-mail dated 01/24/08 from James Pachl
  - "A California Challenge – Flooding in the Central Valley: A Report from an Independent Review Panel to the Department of Water Resources, State of California" dated October 15, 2007, http://www.water.ca.gov/news/newsreleases/2008/101507challenge.pdf
  - "Levee report shocks city", Mary Lynne Vellinga & Matt Weiser, Sacramento Bee, January 16, 2008, http://www.sacbee.com/220/story/637772.html
  - "Summary of the Natomas Basin 3% Event Screening Level Levee Certification Analysis" Memorandum for Record, Kevin Knuuti, P.E., Chief, Engineering Division, Sacramento District, U.S. Corps of Engineers, January 11, 2008, http://www.spk.usace.army.mil/projects/civil/natomascertification/mfrsummary.pdf

Contact Information: Arwen Wacht (808-1964)

Please include this supplemental material in your agenda packet. This material will also be published to the City's Intranet. For additional information, contact the City Clerk Department at Historic City Hall, 915 I Street, First Floor, Sacramento, CA 95814-2604 ▪ (916) 808-7200.

From: James Pachl <jpachl@sbcglobal.net>
To: Scot Mende <SMENDE@cityofsacramento.org>, Arwen Wacht <AWacht@cityofsacramento.org>, Rochelle Amrhein <rwamrhein@cityofsacramento.org>
Date: 1/24/08 9:55AM
Subject: <no subject>

Scot,

As you know, comments and information can be submitted for the administrative record in CEQA until the Council takes action. Last Tuesday the Council passed an intent motion, but final Council action is not until next Tuesday January 29, 2008. I offer the following three documents for inclusion in the administrative record in the Greenbriar matter and for Council consideration prior to their action scheduled for January 29, 2008.

1. Electronic copy of the DWR document released last week (dated October 15, 2007,) titled California Challenge, Flooding in the Central Valley". I submitted a paper copy to Planning last Tuesday 1/22/08, noon, along with my written letter commenting on Greenbriar, and the clerk receiving it said that she would give it to you. The electronic copy is submitted as a courtesy to City. DWR told me that it does not have paper copies available to the public. I referred to this document in my letter and testimony at Council on January 22.

2. Sacramento Bee "Study: Plan for Bigger Floods", January 18, 2008, regarding the above study.

3. Electronic copy of U.S. Army Corps of Engineers ³Memorandum for Record: summary of the Natomas Basin 3% Event Screening Levee Certification Analysis,삲 January 11, 2008, which you can access on Corps of Engineers public website. It is the Corps summary of its assessment of the Basin ability to withstand a 30-year flood event. I referred to the Corps assessment and findings in my testimony to Council and letter dated January 22, 2008.

Thank you very much

Jim

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A California Challenge—
Flooding in the Central Valley

A Report from an Independent Review Panel to the Department of Water Resources, State of California

October 15, 2007

Cover image note: the image showing floodwaters surrounding the Arco Arena in Sacramento, California on the cover of this document has been edited and is not authentic. It was made to illustrate the depth of flooding predicted if that area of Sacramento were to experience levee failure or overtopping and thus be subjected to deep flooding. Used by permission from the California Department of Water Resources.

A California Challenge—
Flooding in the Central Valley

A Report to the
Department of Water Resources, State of California

Independent Review Panel

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October 15, 2007

[1]Mr. Plasencia and Mr. Larson assisted Mr. Thomas in this endeavor.
[2]Mr. Dircke assisted Mr. Wijsman in this endeavor.

Acknowledgements

The Panel would like to express its appreciation to the staffs of the California Department of Water Resources, the U.S. Army Corps of Engineers, the U.S. Federal Emergency Management Agency, and the U.S. Geological Survey for their assistance in locating and providing data to support this report and to the members of the California Floodplain Management Task Force, who in 2002, developed a forward-looking framework for dealing with floods in California.

The Panel would also like to acknowledge the excellent support of the Sacramento office of PBS&J, and the editorial assistance of Lillian L. McAnally, Senior Technical Editor, and Gary Guhl, PE, PBS&J.

Meeting the Challenge: An Executive Summary

California's Central Valley faces significant flood risks.[3] Many experts feel that the Central Valley is the next big disaster waiting to happen. This fast-growing region in the country's most populous state, the Central Valley encompasses the floodplains of two major rivers—the Sacramento and the San Joaquin—as well as additional rivers and tributaries that drain the Sierra Nevada mountains. Expanding urban centers lie in floodplains where flooding could result in extensive loss of life and billions in damages. Recent inspections have raised serious questions as to the integrity of many levees that protect communities and property in the Central Valley. Conservative estimates of potential direct flood damages in the Sacramento area alone exceed $25 billion. In some areas of the Central Valley, communities would experience flood depths of twenty feet or more when the levees fail. A flood of such magnitude and depth not only poses a serious risk to public health and safety but it would cripple the state's economy, and the consequences of such an event would have far-reaching and long-term effects on the nation as well.

The current flood control system of the Central Valley is incapable of dealing with the threat of severe flood events, placing its urban centers at considerable risk while incurring significant environmental costs.

To deal with the challenge of managing Central Valley flooding, over the past 150 years, the federal government, in cooperation with the State, has constructed a system of levees, backed by dams, floodways, and flood channels, designed to control flooding on both urban and rural landscapes. Unfortunately, this aging flood-control system provides only limited protection. Many of the system's levees were poorly built or placed on top of inadequate foundations; others have been inadequately or intermittently maintained. In addition, efforts to protect the Central Valley from flooding have also significantly degraded the natural and beneficial functions of the rivers and their floodplains, threatening the loss of species, destroying habitat, and failing to take advantage of the

[3] There are two sides to this risk: the probability of flooding, and the consequences that would follow. An area could have a high probability of flooding but minimal consequences because the area subject to flooding is forested and contains no infrastructure or people, so the risk is low. Conversely, a highly urbanized community that has a moderate or low probability of flooding would be considered high risk, because the consequences of a flood in that location (loss of life, livelihood, property, health and human suffering) would be very high. We manage the probability side of risk with levees and other structures to control flooding. We manage the consequences side by making land-use decisions that keep infrastructure out of harm's way, or by reducing the consequences to existing infrastructure using a multitude of floodplain management methods.

The Panel recommends that California officials at the state and local levels develop and rapidly act on a comprehensive approach to flood-risk reduction that includes integration with other basin water management activities and, of great importance, with land-use planning.

floodplain's natural capacity to store flood waters and to recharge aquifers below them. The current flood control system of the Central Valley is incapable of dealing with the threat of severe flood events, placing its urban centers at considerable risk while incurring significant environmental costs.

While there is great concern for the current condition of the Central Valley flood control system, the outlook for the future under business-as-usual is grim. Climate change may be increasing the magnitude and frequency of large storms; new understanding of threats, such as those caused by seismicity are emerging; communities aggressively promote new development on the floodplains; and the flood control infrastructure continues to age. The magnitude of the risk to the Central Valley, to California, and to the nation appears to grow for the foreseeable future.

This paper was prepared at the request of the Department of Water Resources by an independent Panel of flood and floodplain management experts from across the nation to provide insights and recommendations on how California should deal with the special circumstances of deep floodplains in the Central Valley[4] (see Panel biographies in Appendix A).

The Panel believes that California state and local governments, with support of relevant federal programs, must develop and rapidly act on a comprehensive approach to flood risk reduction in the Sacramento and San Joaquin Basins, integrating this effort with other basin water management activities and, of great importance, with land-use planning. It is this latter element—land-use planning that connects local land use decision-making with regional flood management—that is critical to reducing future flood risk in the Central Valley.

Levees and other flood damage reduction structures only reduce the dangers of flooding; they do not eliminate them. Indeed, the most extreme and dangerous events are those that are not eliminated. As the state and nation have learned in the last two decades, levees can fail and when they fail, the failure brings catastrophic consequences to those who depend upon them for flood protection. The challenge then is for California to provide comprehensive protection to those now living behind levees, manage risk by mitigating adverse consequences when flooding occurs, and restrict future development in hazardous areas. This will require the state to take the steps necessary to ensure that the

[4] The Panel defines deep floodplains as floodplains where the level of flooding is three feet or higher. In deep floodplains, the ability to evacuate is limited or non-existent, creating significant life-safety threats and the damage to property is extensive.

flood damage reduction system that it puts into place provides a level of protection to those already behind levees that is commensurate with the consequences of failure or overtopping. California also has to take steps, through General Plans, zoning codes, building codes, floodproofing, and evacuation planning, to minimize flood damages and mitigate losses when they occur.[5] The state must also take action to restrict development in high-hazard areas where current population densities are low. Additional development in these areas will simply put more people at risk and create an ever-escalating demand for additional flood damage reduction structures with high economic, societal, and environmental costs.

To deal with these flood problems, the state and local governments, in coordination and with the support of the federal government must carry out the actions listed below. These actions should be treated as an integrated package and not as independent efforts as the success of one action is dependent on the success of the others.

- Provide the highest level of risk reduction feasible to existing urban areas where thousands of people are at unacceptably high risk. The Panel believes that this level of protection should be equivalent to protection against the Standard Project Flood, which represents a flood that can be expected from the *most severe* combination of meteorologic and hydrologic conditions that are considered *reasonably characteristic* of the region. Providing this level of protection does not, by itself, prevent the failure of the system or of individual levees; nor does it guarantee that the Standard Project Flood cannot be exceeded in rare circumstances.[6] One hundred year protection is not an acceptable level of protection for urban areas.
- Develop an implementation plan for providing this reasonably high level of protection for all urban areas.

The Level of Protection for urban areas should be equivalent to protection against the Standard Project Flood. This level of protection does not, by itself, prevent the failure of the system or of individual levees; nor does it guarantee that the Standard Project Flood cannot be exceeded in rare circumstances.

[5] California recently enacted legislation that would require the land use element to identify and annually review those areas covered by the general plan that are subject to flooding as identified by floodplain mapping prepared by FEMA or DWR. The bill also would require, upon the next revision of the housing element, on or after January 1, 2009, the conservation element of the general plan to identify rivers, creeks, streams, flood corridors, riparian habitat, and land that may accommodate floodwater for purposes of groundwater recharge and stormwater management.

[6] Since it is based on estimates of typical meteorological events, the SPF is not associated with a specific return interval (as is the 100-year flood). It is, however, in the Central Valley watersheds generally considered to fall within the 200- and 500-year return period as developed using national computation methods.

The state should continue to support the Federal Emergency Management Agency's levee policy and assist them in accelerating completion and adoption of updated flood maps.

The needed level of flood protection should be phased in with at least a 200-year level of flood protection to be achieved by 2020, and Standard Project Flood protection by 2030. Priority should be given to urban areas in deep floodplains.[7]

- In less populated areas, provide for protection against less severe floods (e.g. less than 200-year protection) as economically and environmentally justified, and maintain that lower level of protection into the future.
- Ensure that any flood protection provided is sustainable fiscally and physically over time.
- Manage the floodplain by focusing new development outside of the floodplain or in low-risk locations within protected areas of the floodplain, supporting the use of undeveloped and unprotected land for agriculture and other low-intensity land uses.[8] Floodplain management should be accompanied by requirements for local governments to adopt *and enforce* needed land-use controls, financial and technical support to enable them to do so, and appropriate penalties if local governments fail to manage development to reduce flood risk. The state should continue to support the Federal Emergency Management Agency's levee policy and assist them in accelerating completion and adoption of updated flood maps. This would ensure that any new development in areas behind inadequate levees takes place under the land-use provisions mandated by the National Flood Insurance Program, as a minimum.
- Site, where feasible, new levees or major rehabilitation of levees at a distance from the river and from existing levees. This would provide a degree of redundancy in the system, increase the land available for habitat and flood storage, reduce operation and maintenance costs, and help to ensure the integrity of the structures. Levees built this decade will be in place for decades to come, and

[7] Private development of levees should be limited to those cases where the construction meets national levee standards, the project is in conformance with the state's comprehensive plan for flood damage reduction, and a public agency agrees to provide long-term maintenance of the levee.

[8] California recently enacted legislation imposing restrictions on development unless significant progress is made towards a 200-year level of flood protection for urban areas. While it does not go into effect for enforcement until 2015 and therefore is not as timely as the Panel would like, it is at least a step in the right direction.

now is the time to begin building structures that will last. Where re-siting is not feasible, the existing flood system should be modified to mitigate the impacts of floods that exceed the design level of the system.

- Mitigate potential financial losses to those behind levees and to those in the non-leveed 500-year floodplain shown on Federal Emergency Management Agency flood maps[9] through institution of mandatory purchase of flood insurance, or through inclusion of flood insurance in homeowners' policies of those within these areas.
- Share the liability for flood damages among state and local governments. This would ensure that any local governments making land-use decisions that could increase potential flood damages share not only the benefits of that development, but also any liability incurred from potential flood consequences should those decisions prove to have been unwise.[10]
- Communicate to the public and each property owner in the floodplain the specific risks of occupying areas at risk of flooding, and provide steps property owners can take to reduce their exposure to flood damages.[11]
- Work together with the development, environmental, and business communities, and with citizens. Outreach and coordination with these groups is vital to the success of any floodplain management program for the Central Valley.
- Supplement the structural protection provided with floodproofing, elevation of homes and businesses, land-use regulations, and other non-structural approaches to reduce the residual risk that will continue to exist. Support this with emergency response systems including the development of post-disaster sheltering and redevelopment plans and the exercising of floodplain evacuation plans on a regular basis.

Supplement the structural protection provided with floodproofing, elevation of homes and businesses, land-use regulations, and other non-structural approaches to reduce the residual risk that will continue to exist.

[9] Careful attention will have to be paid in FEMA's remapping of Central Valley floodplains to ensure that the extent of the 500-year floodplain is calculated using techniques that accurately reflect the situation in the Central Valley.

[10] California recently enacted legislation to hold local governments financially liable if they unreasonably approve new development in floodprone areas.

[11] California recently enacted legislation that would require DWR to provide yearly written notice to each landowner whose property is determined to be within a levee flood protection zone.

Dealing with flooding in the Central Valley will require a close examination of existing governmental institutions and how they work together. The lessons learned from the New Orleans disaster point out the disconnects that develop when too many agencies are involved in the decision-making process and no one agency has overall direction. Large flood events exploit those disconnects. California must address this difficult issue, especially in terms of the large number of overlapping roles, responsibilities and accountabilities of reclamation districts, and state and local governments. Without reforming the institutions that manage flood protection, large investments in infrastructure are likely to be wasted.

California faces a severe flood challenge in the Central Valley.

People and property behind levees are subject to significant residual risk.

Every effort should be made to limit development in areas now at risk behind levees and in unprotected areas.

Areas where the consequences of flooding would be significant—where there would be loss of life or extensive property damage—should be protected at the highest level.

In all areas subject to flooding, active mitigation measures should be taken including mandatory insurance in the floodplain and behind levees.

Concurrent with the development of adequate flood protection, attention must be paid to restoration of the natural beneficial functions of the floodplain.

Floodplain restoration should be a priority, both to mitigate for the environmental impacts of flood management infrastructure and because floodplain restoration projects can actually reduce flood risks.

Robert A. Eplett/OES CA

1 The Central Valley's Vulnerability to Flooding

Flooding in the Central Valley

FEMA News Photo 1166/Robert A. Eplett

The Central Valley of California faces significant flood risks. In January 1997, one of the most extensive and costly floods in the State's history occurred when more than thirty levees ruptured and three hundred square miles in the Central Valley were inundated by floodwaters.

A combination of recent factors including escalating development, deferred maintenance, reduced funding, and recent court decisions have put public safety and the state's financial stability at risk for even greater calamity in the future.

Significant flooding occurred on fifteen rivers where historical peaks were approached or exceeded. Forty-eight counties were declared disaster areas. The flooding caused one hundred-twenty thousand people to evacuate their homes and nine people lost their lives. Damages approached $2 billion and floods affected over twenty-three thousand homes as well as numerous businesses, agricultural lands, bridges, roads, and flood infrastructure. Estimated indirect costs and costs associated with the disruption of the state's economy exceeded $5 billion.[12]

As chronicled in the book, *Battling the Inland Sea,* California's 1997 flood is just one example of flooding that, over the decades, has caused significant loss of life and property to Californians.[13] A 2005 Department of Water Resources document, *Flood Warnings: Responding to California's Flood Crisis,* pointed out that, "...a combination of recent factors has put public safety and the state's financial stability at risk for even greater calamity in the future:

- Escalating development in floodplains increases the potential for flood damage to homes, businesses, and communities.

[12]State of California, Department of Water Resources, *Alternatives for Increasing Flood Insurance Participation for Communities Behind Levees in California,* May 2006.

[13] Robert L. Kelly, *Battling the Inland Sea: Floods, Public Policy, and the Sacramento Valley*, University of California Press, 1989.

Those living behind levees believe that they are protected and have little understanding of the residual risk they face from levee failure or levee overtopping.

- California's flood protection system, comprised of aging infrastructure with major design deficiencies, has been further weakened by deferred maintenance.
- State and local funding for effective flood prevention and management programs has been reduced.[14]
- Court decisions have resulted in greater state flood damage liability."[15]

The Central Valley's flood-control system includes approximately 1,600 miles of state/federal levees and thousands of additional miles of privately-owned and locally-maintained levees that were built primarily to protect agricultural areas.[16] Studies that are underway to uncover underseepage areas will detect some of the hidden deficiencies that can be repaired but there is no "one time sure fix" on the horizon for a system designed and built by numerous parties over a number of years. As a result, failures must be anticipated to occur unpredictably and with little warning.[17]

In addition, levees in the Central Valley continue to deteriorate due to natural and system-induced erosion, degradation and/or removal of natural berms, animal burrows, settlement, inadequate maintenance, and the build up of sediment deposits which, in some areas, have greatly reduced the amount of water that flows through critical bypass channels and river segments.[18]

Levee reliability issues are not the only problems facing the Central Valley. For the most part, those living behind federal or state levees believe that they are protected and have little understanding of the residual risk they face from levee failure or levee overtopping. The national focus on the 100-year standard for levee accreditation by the National Flood Insurance Program has led many to believe that protection to that level provides assurance against any flooding.

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[14] Since the issuance of the cited report, funding at the state level has been greatly increased with an unprecedented $5 billion now available over the next ten years to address the situation of aging levees and institute other flood protection measures.

[15] State of California, Department of Water Resources, *Flood Warnings: Responding to California's Flood Crisis*, January 2005.

[16] The state did not have an accurate inventory of levees until they began a levee inventory in 2005, which is still ongoing.

[17] State of California, Department of Water Resources, *Flood Warnings: Responding to California's Flood Crisis*, January 2005.

[18] Ibid.

Levees in the Central Valley

Levee reaches shown are based on the latest California Department of Water Resources levee database.

Floodprone Areas in the Central Valley

The area shown at risk on this map is subject to change, and will likely increase.

This map is based existing FEMA data.

Levee stability analyses have not been completed for significant areas of the Central Valley.

Flood risk analyses have not been completed for significant areas of the Central Valley.

2 Current Exposure in Deep Floodplains

There is no accurate record of the current exposure in the Central Valley's deep floodplains, although estimates have been made. In the paper, *Alternatives for Increasing Flood Insurance Participation for Communities Behind Levees in California*, the California Department of Water Resources commissioned an examination of the possible monetary impacts of a levee failure in several Central Valley communities, and compared that to information about National Flood Insurance Program flood insurance participation in the affected areas.

The results of the analysis show that, during a 200-year event, more than half of the residents and business owners damaged by flooding will not be covered by flood insurance. For the 500-year event, the uninsured segment rises to 64%.

The damage estimates used for the analysis did not include flood fighting costs, levee repair costs, pumping out/clean up costs, utility infrastructure damages, rescue or evacuation costs, costs associated with disruption of services, lost business or personal income, social disruption, injuries, health and human suffering consequences, or loss of life. As the nation learned after Katrina, there can be unforeseen consequences from large flood events that can dramatically increase the monetary damages from previous assessments. In addition, increased population and associated development in deep floodplains will increase the numbers of those at risk even further.

During a 200-year flood event, more than half of the residents and business owners will not be covered for flood damages in the communities studied. That number rises to 64% during a 500-year event.

	200-Year Flood[19]			
Community	Estimated Damages	Parcels Damaged	Parcels Insured	Percent of Damaged Parcels *Not* Insured
Dos Palos	$0.4 million	0	5	0%
Firebaugh	$4.0 million	725	225	69%
Gridley	N/A	N/A	27	0%
Lathrop	$214.9 million	2,265	59	97%
Marysville	$99.2 million	3,554	826	77%
Modesto	$141.2 million	889	244	73%
Sacramento	$9.5 billion	78,940	40,876	48%
West Sacramento	$351.8 million	5,483	1,980	64%
Yuba City	$308.4 million	12,932	2,182	83%
Total	**$10.6 billion**	**104,788**	**46,424**	**56%**

	500-Year Flood[19]			
Community	Estimated Damages	Parcels Damaged	Parcels Insured	Percent of Damaged Parcels *Not* Insured
Dos Palos	$1.7 million	726	6	99%
Firebaugh	$4.8 million	725	246	66%
Gridley	$8.7 million	1,041	30	97%
Lathrop	$259.3 million	2,265	65	97%
Marysville	$236.5 million	3,554	900	75%
Modesto	$231.6 million	2,273	267	88%
Sacramento	$13.9 billion	109,700	44,509	59%
West Sacramento	$685.7 million	5,494	2,156	61%
Yuba City	$683.2 million	13,301	2,377	82%
Total	**$16.0 billion**	**139,079**	**50,556**	**64%**

[19] N/A – No expected damages.
-Insurance information was obtained from FEMA's Community Information System database, and is current as of June 2007.
-Flood damage estimates for all communities are based on the 2002 *Sacramento and San Joaquin River Basins Comprehensive Study*, and damage estimates were converted to 2005 dollars. Parcel data for damage estimates are based on 2000 conditions.
-Flood damage estimates include structural damage and damage to contents. Many flood insurance policyholders do not have contents coverage.
-Flood damage estimate fir Dos Palos 200-year includes damages to two farmsteads.
-The damage estimates used for the analysis did not include flood fighting costs, levee repair costs, pumping out/clean up costs, utility infrastructure damages, rescue or evacuation costs, costs associated with disruption of services, lost business or personal income, social disruption, injuries, health and human suffering consequences, or loss of life.
-The City of Stockton was not included in these estimates because the *Comprehensive Study* included the main stems of the Sacramento and San Joaquin Rivers only, and excluded most of the central Delta region where Stockton is located. Comparable damage estimates and number of parcels damaged for 200- and 500-year events could not be located for Stockton from other sources.

2 Future Exposure in Deep and High-Risk Floodplains

Climate change and the growth, density, and value of new development in the floodplain threaten to dramatically increase the population subject to flooding in the Central Valley. The effects of climate change will impact future exposure in deep floodplains because it will affect air temperature, precipitation, runoff, and sea level. Flood heights may rise in high-risk areas, and areas currently considered to be at low vulnerability may become high-risk areas in the future.

Climate change and the growth, density, and value of new development in the floodplain threaten to dramatically increase the population subject to flooding in the Central Valley.

A 2002 report by the California Regional Assessment Group on the potential impacts of future climate change in California indicates that global average precipitation will increase, and that temperature increases in mountainous areas with seasonal snowpack will lead to decreases in the length of the snow storage season and increases in the ratio of rain to snow. It is possible that reductions in snowfall and earlier snowmelt and runoff would increase the probability of flooding early in the year and reduce the runoff of water during late spring and summer.

The report notes that basins in the western United States are particularly vulnerable to such shifts, and that there is a risk of increased flooding in parts of the U.S. that experience large increases in precipitation. Flows currently associated with 100- and 500-year floods may occur more frequently as a result of increased precipitation and other changes related to climate change. The report further states that, "...in the not-too-distant future, the notions of one-hundred-year and five-hundred-year floods may completely lose their meaning and usefulness as planning tools. Some suggest they already have."[20] This indicates that the expected changes in hydrology caused by climate change will cause our current estimates of 100- and 500-year floods to be inaccurate in the future.

The 2004 report, *Is the 1% Chance Flood Standard Sufficient?*[21] concluded that, "The prescriptive 1% chance standard oversimplifies complicated concepts. Much happens within the floodplain that cannot be captured in a simple 'in or out' determination. Although such simplicity has its appeal, a broader, more flexible approach would allow for the reflection of more detail

[20] *Preparing for a Changing Climate, The Potential Consequences of Climate Variability and Change: A Report of the California Regional Assessment Group For the U.S. Global Change Research Program*, September 2002.

[21] Association of State Floodplain Managers Foundation, *Reducing Flood Losses: Is the 1% Chance (100-year) Flood Standard Sufficient?* September 2004.

and more accuracy." Because of the standard, development has tended to cluster just outside of the 1% floodplain boundary, an area not free from flood risk and possibly subject to considerable risk now that watersheds have been urbanized and runoff thereby increased.

California is also undergoing a population boom. The state's population is expected to grow by 17.6 million between now and 2050. Some of the housing and other development needed for this population growth could occur in deep floodplains. A study of data from the U.S. Census, the Department of Water Resources, and the U.S. Army Corps of Engineers, shows that 1.8 million people rely on levees for flood protection in California's Central Valley. If the current level of growth continues unchanged, projections estimate that, by 2020, the number will rise to more than 2.3 million.

Projected Population in Areas Behind Levees in the Central Valley[22]

County	1990 Census Population[23]	Est. 2005 Census Population[24]	Projected 2020 Population[25]
Alameda	0	10	20
Butte	43,060	52,410	61,760
Colusa	10,020	11,290	12,560
Contra Costa	10,750	15,530	20,310
Fresno	28,700	38,600	48,500
Glenn	3,780	4,230	4,680
Kern[26]	230,370	301,660	372,950
Kings	53,210	78,220	103,230
Madera	13,050	17,950	22,850
Merced	43,530	54,240	64,950
Placer	130	130	130
Sacramento	457,640	562,410	667,180
San Joaquin	292,340	390,460	488,580
Solano	3,820	7,180	10,540
Stanislaus	16,050	24,790	33,530
Sutter	67,800	90,630	113,460
Tehama	940	900	860
Tulare	62,740	90,050	117,360
Yolo	62,520	87,290	112,060
Yuba	37,280	41,190	45,100
Total	**1,437,730**	**1,869,170**	**2,300,610**

[22] The information shown is an estimate and provides the first step in identifying the populations behind levees for the Central Valley. Population living behind levees denotes both Federal and Non-Federal Levees.
[23] Based on the extrapolation of the 1990 and estimated 2005 U.S. Census Data.
[24] Based on the estimated 2005 U.S. Census Block Groups.
[25] Based on the 1990 U.S. Census Block Groups.
[26] The Kern County population protected by levees was large due to many Non-Federal Levees surrounding the county, mainly Canal and Aqueduct Levees. These levees provide some type of protection identified in the topography.

Current development in the Central Valley's deep floodplains is in progress because these areas are close to population centers and offer easy-to-build-on land. Those doing this building assume or have been led to believe that adequate flood protection will be provided by the government. New development in deep floodplains will continue until it is clear (to communities, developers, and citizens) that the long-term costs of building in these areas to the public at large and to the floodplain residents in particular, outweigh any short-term benefits. Legislative efforts mandating that local governments accept a portion of the flood liability are an uphill battle with term-limited members keenly aware of the political cost of such a decision.

3 Floodplain Management in the Central Valley

Much of the current infrastructure is old, is of questionable integrity, and the degree of protection provided is minimal in comparison to the possible consequences of flooding.

Robert A. Eplett/OES CA

In California (and across the nation), the past approach to preventing flood damage to those who lived in flood-prone areas was focused on controlling floods. Dams, floodways, channels, levees, and other structures were built over time to restrain and store floodwaters, move floodwaters away from occupied areas, or pass them safely by these areas. Much of the current infrastructure is old, is of questionable integrity, and the degree of protection provided is minimal in comparison to the possible consequences of flooding. Additionally, even the most perfectly engineered, impeccably maintained levee will be overtopped during a flood event that exceeds its design capacity.

The Sacramento Valley has large dams, relatively generous floodway[27] capacities, and has not experienced significant exceedance of the modern design capacity of its floodwater management system. However, the 2005 Department of Water

[27] Designated Floodway refers to the channel of the stream and that portion of the adjoining floodplain reasonably required to provide for the passage of a design flood; in California, it is also the floodway between existing levees as adopted by The Reclamation Board or the state Legislature.

Resources document, *Flood Warnings: Responding to California's Flood Crisis*, indicates that, "... levee heights and channel capacities [in the Central Valley] have been designed using historical data related to precipitation and runoff. However, due to either limited historical data or climate change, the general trend is for flood flows to be higher than anticipated. Consequently, flood inundations by 100-year flood events now cover much greater areas than those used for design and floodplain mapping just a few years ago."[28]

"...flood inundations by 100-year flood events now cover much greater areas than those used for design and floodplain mapping just a few years ago."

Within the Sacramento basin, there are deep floodplains with both large rural and urban areas in those "protected" areas. Levee reliability and height has been the Sacramento Valley's biggest problem although it is now being addressed in urban areas primarily via levee improvements, floodway corridor/bypass expansions, some planned (or unplanned) floodplain flooding, improvements to existing dams, and operational changes to dams.

Some of these improvements should be easy to undertake; some are very expensive and politically challenging. Floodplain management programs are spotty. Where levees are certified by local authorities or the U.S. Army Corps of Engineers and mapped by the Federal Emergency Management Agency's National Flood Insurance Program as providing protection against the 100-year flood (the current condition for most of the Sacramento River levee system), those living behind the levees are not required to elevate structures and there are no requirements to purchase flood insurance. Once the levee fails or is overtopped, the costs and consequences will be catastrophic.

The San Joaquin Valley is also rimmed with dams, but floodway capacities in this system are small and designed for managing snow-melt flooding. Unregulated rain-flood flows from many dams are quite foreseeable (and occurred in 1997), in part because major reservoir-flood-space encroachments can occur from storms that may have happened days, weeks, or even months earlier. Only some of the San Joaquin levees have been certified, have received accreditation status from the Federal Emergency Management Agency, and are mapped as providing protection from 100-year flooding.[29]

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[28] State of California, Department of Water Resources, *Flood Warnings: Responding to California's Flood Crisis*, January 2005.

[29] Reviews being conducted as part of FEMA's Map Modernization may result in the decertification of many of the levees in both basins, forcing the implementation of minimum federal floodplain management programs in the areas.

Risk management approaches in the San Joaquin basin are largely the official recognition of floodplain flooding and some relatively minor levee improvements and setbacks. In contrast to the Sacramento Valley, in the San Joaquin Valley, the effectiveness of dam operation for modification of rain-generated floods is substantially limited by the Valley's minimal floodway capacity. The first flood fills the reservoir, and evacuation of the water is limited by the downstream channel capacities. This makes the likelihood of spilling large flood flows from the reservoir much greater during subsequent flood events. Expansion of floodways in tributary streams would be very helpful for dam operations during floods if the water could be either safely routed through the Sacramento/San Joaquin River Delta or into valley-bottom floodplains.

4 Managing Flood Risk

Generally, there are three basic approaches to flood risk management:

1. Avoid using the floodplain for activities other than those compatible with periodic flooding.
2. Minimize damages from floods to the maximum feasible extent by building and maintaining levees, flood walls, dikes, reservoirs, channelization of streams, bypasses, and the like; instituting floodplain development requirements such as land-use controls which minimize new unsafe development in high-risk areas and by retrofitting existing structures; and having robust and effective evacuation plans and warning systems to get the people out of harm's way should the need arise.
3. Mitigate losses to those who are subject to flooding through self-help, by providing indemnification through government payments (direct or as a result of litigation), or through forms of public and private insurance. (See Appendix B).

It is more efficient to prevent catastrophic damages to the maximum extent possible, than to do nothing and deal with a flood after it occurs.

Foregoing these approaches means, sooner or later, spending time and resources recovering from the disaster that will occur. It is more efficient to prevent catastrophic damages to the maximum extent possible (and, in the event of exceptional floods that inundate protected floodplains, to have prepared for and minimized the adverse consequences and facilitated a rapid recovery), than to do nothing and deal with a flood after it occurs.

The first line of defense against flood risk should be to avoid or minimize damages through land-use controls and regulations for safe floodplain development. Levees and other structural flood control measures should provide a secondary source of risk reduction.

It is important to understand that a home built behind a levee designed to provide protection from the 100-year flood is at greater risk than a home built to the 100-year flood elevation for a number of reasons. First, the consequences of a flood that exceeds 100-year levels will have vastly different consequences for the two homes, as illustrated in the graphic on Page 19. Second, the home behind the levee is at risk of inundation due to levee failure during floods less severe than the design flood. Levee failure may be the consequence of poor construction, poor maintenance, undetected

Determination of the appropriate design level for flood risk reduction structures must be based on the probabilities of occurrence of the hazard and the consequences of flooding should the design level be exceeded or the system fail before that design level is reached.

rodent activity, undetected geotechnical problems, seismic events, or other unforeseen factors.

Determination of the appropriate design level for flood risk reduction structures must be based on the probabilities of occurrence of the hazard and the consequences of flooding should the design level be exceeded or the system fail before that design level is reached. Recent studies of the development of long-term protection of New Orleans and coastal Louisiana have determined that it is not feasible to provide all areas with the same level of protection—that the flood protection level provided must be risk-based, accounting for the consequences of flooding as well as the associated probabilities of occurrence.

Level of Protection represents the ability of a structure or a system to contain a flood of a given size with a high degree of assurance. It can be defined by three different methods:

- As the average return period in years (e.g. 100-year, 500-year, etc.) of the largest flood that can be expected to occur at that average frequency;
- As the maximum derived discharge expected from a flood developed from a set of specific hydrological conditions (e.g. as the Standard Project Flood); or
- As the discharge of a significant historical event.

Return periods are based on statistical analysis of information gathered about previous floods in the region. Most experts agree that for a flood record length of 100 years, the flood estimates extrapolated from the data should not exceed 200 years. The confidence in the accuracy of a larger-than-200-year flood elevation that is based on a short 100-year record of weather and storm data is lower than it is for estimates of 200-year or less. It should be noted that the period of record is often less than 100 years in the U.S.

Floods defined by a derived discharge are developed by combining theoretically possible storms with, where appropriate, snow melt over a basin and computing the resultant flood discharge. The Level of Protection can also be expressed in terms of the ability of the system to contain a specific historical flood of record (e.g. The 1997 Flood).

In the design of the system, all three methods must take into account the hydraulic characteristics of the basin, the uncertainties connected with the data available, and the events those data represent.

In most cases, in determining the Level of Protection to be used in a specific situation, the results of all three methods are compared and the method determined most suitable for the basin is used in the design of the levee or other flood control structure. The utility of each method is driven by the quality and amount of data available (e.g. accuracy, length of record, etc.). The final determination requires considerable professional judgment.

A 100-year flood is that flood that has a 1% chance of occurrence in any given year; a 500-year flood has a 0.2% chance of occurrence in any given year. However, the occurrence of a 100-year flood in a given year does not mean that a similar or larger flood can not occur in the following year, or even later that same year. As a result of this yearly independence, there is a 26% chance that a 100-year flood will occur or be exceeded within a 30-year period (the life of a typical mortgage).[30]

Since the determination of the 100-year flood is based on an examination of the available record, the occurrence of a new major flood will cause this new event to be added to those records. This could result in a recalculation of the 100-year flood estimate. Large floods have occurred after which recalculations show that the previously-determined 100-year flood elevation was incorrect. After the 1993 flood on the Mississippi River, federal agencies launched a program to recalculate 100-year flood elevations along the Mississippi and Missouri Rivers and determined that, as a result of the information developed from the 1993 flood, 100-year estimates changed. For the lower portion of the Upper Mississippi River, new flood levels varied widely—lowering 1.5 feet in some areas and rising nearly two feet in others. On the lower Missouri River, flood levels remained the same or rose as much as four feet.[31]

The Standard Project Flood, a "derived discharge" estimate, represents a flood that can be expected from the most severe combination of meteorologic and hydrologic conditions that are considered *reasonably characteristic* of the region. Where floods

The Standard Project Flood represents a flood that can be expected from the most severe combination of meteorologic and hydrologic conditions that are considered reasonably characteristic of the region.

[30] A 2004 Report by the Association of State Floodplain Managers Foundation, *Reducing Flood Losses: Is the 1% Chance Flood Standard Sufficient?* concluded that "The prescriptive 1% chance standard oversimplifies complicated concepts. Much happens within the floodplain that cannot be captured in a simple "in or out" determination. Although such simplicity has its appeal, a broader, more flexible approach would allow for the reflection of more detail and more accuracy." Because of the standard, development has tended to cluster just outside of the 1% floodplain boundary, an area not free from flood risk and possibly subject to considerable risk where watersheds have been urbanized and runoff thereby increased.

[31] The U.S. Army Corps of Engineers, Rock Island District, *Upper Mississippi, Lower Missouri, and Illinois Rivers System Flow Frequency Study, Final Report*, February 2004.

Level of Protection represents a determination by decision makers of the level of risk that they are willing to accept for the area being protected. This must be balanced against the economic and engineering feasibility of providing that level of protection.

are predominantly the result of melting snow, the SPF is based on estimates of the most critical combinations of meteorological events (snow, rain, temperature, etc.) considered reasonably characteristic of the region. Since it is based on estimates of typical meteorological events, the Standard Project Flood is not associated with a specific return interval (as is the 100-year flood). It is, however, in the Central Valley watersheds generally considered to fall within the 200- and 500-year return period as developed using national computation methods.

The U.S. Army Corps of Engineers indicates that the Standard Project Flood, "is intended as a practicable expression of the degree of protection to be considered for situations where protection of human life and high-valued property is required, such as for an urban levee or floodwall."[32] It was the de facto U.S. Army Corps of Engineers standard until the 1980's when the institution of local-federal cost sharing for levee construction began. At that time, it became economically beneficial for communities to build only to the 100-year standard, given that achievement of 100-year protection removed the community behind the levee from the insurance and land-use requirements (and costs) of the National Flood Insurance Program and reduced the size (and the local costs) of the levee construction.[33]

Level of Protection represents a determination by decision makers of the level of risk that they are willing to accept for the area being protected. This must be balanced against the economic and engineering feasibility of providing that level of protection. The Netherlands and Japan provide 10,000-year protection for coastal areas, and, on the lower Rhine, the Netherlands seeks to provide 1250- to 2000-year protection. While the methods of calculation of these recurrence intervals may differ from those used in the U.S., the intention of the governments is clear: to protect the population against extremely large and rare flood events. During the Department of Water Resources levee workshop on July 27, 2007, the Netherlands representative, citing New Orleans as an example, noted that adequate prevention of floods is far cheaper over the long run than the costs of recovery from a disastrous event.

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[32] USACE Engineer Manuals: EM 1110-2-1411 and EM 1110-2-1417.

[33] USACE also uses, in its designs, a Probable Maximum Flood (PMF), which is, "the flood that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the drainage basin under study." Assumptions concerning rainfall losses, snowmelt runoff, channel efficiency, etc. are adjusted to produce the largest flood reasonably possible. The PMF is used to design high hazard structures (top of dam, outlet and spillway capacities) where failure cannot be tolerated. (Engineering Pamphlet: EP 1165-2-1). The SPF is typically considered to be 40%-60% of the PMF.

Many reports have provided recommendations on Level of Protection for urban areas:

- The White House study of levee performance during the 1993 Mississippi Flood—the most devastating of the 20th century—recommended that urban areas be protected against the Standard Project Flood, equating such a flood to approximately a 500-year event.
- Similar federal and federally-sponsored studies since Katrina have echoed this recommendation and have recommended that urban levees not be accredited by the National Flood Insurance Program unless they have 500-year protection.
- As stated above, the U.S. Army Corps of Engineers used the Standard Project Flood as its standard for urban areas until the late 1980's when economic analyses were used that did not consider human safety, and the National Flood Insurance Program criteria unintentionally drove the level of protection down to the 100-year level.
- Recommendations to the Federal Emergency Management Agency by its engineering staff and by a National Academy study also urged the use of a greater-than-100-year level of protection for levees protecting population centers.
- Water Resources Council Guidance for implementation of the 1977 Presidential Executive Order 11988, Floodplain Management, requires that federal and federally-supported critical facilities (hospital, police, fire, water and wastewater facilities, etc.) be located outside the 500-year floodplain or protected against the 500-year event.
- In a 2007 White Paper, the Association of State Floodplain Managers notes that, "In those cases in which a levee is found to be an appropriate measure to protect urban areas or to be credited for protection, the levee should be constructed to a high level of protection. As described in various reports, the level of the 500-year flood, plus freeboard, [to account for uncertainties], is considered an appropriate minimum protection standard for constructing and accrediting levees within urban areas."

The Panel believes that the Level of Protection for urban areas should be equivalent to protection against the Standard Project Flood. This level of protection does not, by itself, prevent the failure of the system or of individual levees; nor does it guarantee that the Standard Project Flood cannot be exceeded in rare circumstances.

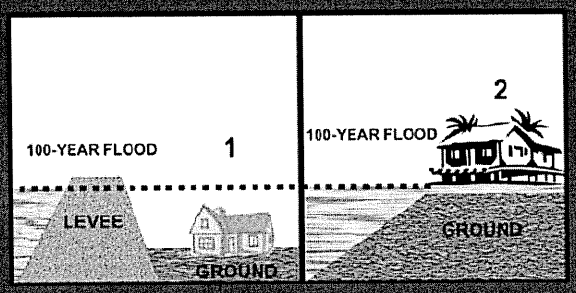
The Panel strongly recommends that the state bring together the expertise of its own technical personnel and technical leaders from the USACE, USGS, the Bureau of Reclamation, business, academe, and others to establish procedures for the calculation of the Standard Project Floods.

The Panel believes that the state and local governments, in coordination with the federal government, should provide the highest level of risk reduction feasible to existing urban areas and that this level of protection should be equivalent to protection against the Standard Project Flood. Priority in this effort should be given to urban areas in deep floodplains. As indicated above, the Standard Project Flood represents a flood that can be expected from the *most severe* combination of meteorologic and hydrologic conditions that are considered *reasonably characteristic* of the region and must be developed for the specific watershed under consideration. The Panel recognizes current challenges faced in computing both the Standard Project Flood and the discharges associated with a greater-than-200-year flood using the purely statistical techniques outlined in Bulletin 17B. Since a determination of the Standard Project Flood is critical to the flood management program, the Panel strongly recommends that the state bring together the expertise of its own technical personnel and technical leaders from the U.S. Army Corps of Engineers, U.S. Geological Survey, the Bureau of Reclamation, business, academe, and others to establish procedures for the calculation of the Standard Project Floods.

The Panel also notes that, no matter how the Standard Project Flood is calculated, the possibility of levee failure during either a less than or greater than Standard Project Flood event is real and should be anticipated and planned for.

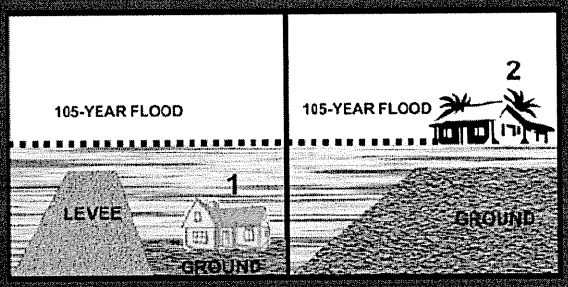
A Question of Consequences: A Tale of Two Properties[34]

A depiction of a non-elevated home in a deep floodplain on the protected side of a levee appears on the left, and a home in which the lowest floor has been elevated to the 100-year flood is shown on the right.



When the 100-year flood occurs, the home on the right is surrounded by floodwaters, but will incur little damage because it has been elevated. The home on the left, of course, is protected by the levee, so no floodwaters are shown to inundate the structure.

However, when a 105-year flood occurs, the situation is dramatically different.



The home on the right is again surrounded by floodwaters, and will sustain some damage, but the home on the left is completely under water and will sustain much more devastating damages than the elevated structure. Add to the equation the fact that the elevated home is likely to be covered by flood insurance, but the home on the left is likely to not be covered, and the consequences are even more substantial.[35]

[34] Images from: Interagency Levee Policy Review Committee, *The National Levee Challenge: Levees and he FEMA Map Modernization Initiative*, September 2006.

[35] Flood insurance requirements are based on whether or not the ground surrounding a home or other structure is below the 100-year flood elevation. Even though the home on the right has its lowest floor elevated to the 100-year flood elevation (the minimum standards of the National Flood Insurance Program), it is still located within the 100-year floodplain and therefore is likely to be required to have flood insurance –more likely than the home on the left, which may have been mapped outside of the 100-year floodplain due to the presence of the levee.

5 Learning From Past Floods

FEMA News Photo 14775/Liz Roll

Flooding is the most costly natural hazard in the nation. Thousands of communities across the country are at risk from flooding from inland storms, snow melt, coastal storm surges, and tsunami flood waves. Until the Mississippi River flood of 1993, which caused an estimated $15 to $20 billion in damages, floods generally caused annual losses of about $4 billion (between 1994 and 2005, annual losses had grown to approximately $6 billion).[36]

During the Mississippi River flood, hundreds of local levees failed or were overtopped and floodwaters inundated more than 17,000 square miles and more than 20 million acres of farmland in nine states of the Missouri and Upper Mississippi River Basins. The flood caused a resurgence of the national debate (but little action) about levees and their influence on communities protected by them, what should be done about structures that have been substantially damaged by flooding, mitigation techniques, and the utility of flood insurance.

[36]Interagency Floodplain Management Review Committee, *Sharing the Challenge: Floodplain Management into the 21st Century,* U.S. Government Printing Office, Washington, DC, 1994.

Past Floods, Lessons Learned.

- Levee failures can, and do, occur. Levees can also be overtopped during a flood event larger than the flood to for which the system was designed. The consequences can be catastrophic.
- Levees and levee systems need to be planned, designed, and maintained in a cohesive fashion. The performance of the system must take overtopping into consideration and include resilience and redundancy in the design.
- With the rapid expansion of knowledge and engineering practice, it is necessary to frequently review the adequacy of existing infrastructure in the context of that new knowledge and have processes in place to respond expeditiously to any performance limitations that arise.
- Risk assessment provides a new and more comprehensive method to understand the inherent vulnerability for areas protected by complex protection systems and subjected to uncertain natural hazards.
- There is a direct correlation between the depth of flooding and losses due to that flooding.
- Disconnects in coordination can develop when too many agencies are involved in decision making and no agency has overall direction.
- There can be great unforeseen consequences from large flood events.

Flood protection structures need to be designed as a part of a complete system-based approach to protection, providing balanced and uniform levels of protection from the perspectives of time, level of hazard, and reliability.

On August 29, 2005, Hurricane Katrina hit the Gulf Coast of the United States, and again entered the nation into a new era of flood risk awareness, especially regarding the risks faced by communities that are protected by levees. And since Katrina, although the Congress has voted for a National Levee Safety Program, little has been done at the national level to deal with the continuing challenge of growing flood vulnerability and losses.

In its Interim Final Report, the Interagency Performance Evaluation Task Force (IPET), chartered to determine the causes of the flooding, noted the following reasons for the extensive levee breaks in the New Orleans area and summarized some of the lessons learned from the Katrina disaster. Below is a synopsis of lessons that are relevant to California:[37]

- Planning and design methods need to be system-based, allowing an in-depth analysis of how a combination of structures and floodplain management measures will perform together. These methods need to be able to consider the performance of the system beyond the design criteria, including the life cycle value of resilience and redundancy in the design. Dynamic factors such as subsidence and changing hazard levels must be included. Flood protection structures need to be designed as a part of a complete system-based approach to protection, providing balanced and uniform levels of protection from the perspectives of time, level of hazard, and reliability. Resilience should be factored into all designs to prevent catastrophic failures. The maintenance condition of levees is an important factor in their overall performance and should be monitored rigorously.

- Knowledge of hydrologic and hydraulic factors and the flood flows and heights that result has increased dramatically over the last decades. Data developed more than ten years ago generally provides an inadequate description for today or for the future. Defining the hazard of the future requires a significantly more sophisticated approach than traditional practice. Peak values alone (water levels generated by storms or flood events) do not characterize risk; full hydrographs are needed to assess both structural performance and potential flooding.

[37] Interagency Performance Evaluation Task Force, *Performance Evaluation of the New Orleans and Southeast Louisiana Hurricane Protection System, Volume I, Executive Summary and Overview*, February 2007.

- Risk assessment provides a new and more comprehensive method to understand the inherent vulnerability for areas protected by complex protection systems and subjected to uncertain natural hazards. It provides a direct view into the sources of vulnerability, providing a valuable tool for public officials at all levels to focus resources and attention on the most serious problems and to seek solutions that reduce risk through both strengthening the reliability of the physical structures and reducing exposure of people and property to losses. Mapping the economic and human health and safety consequences of flooding has created a powerful information base from which risk assessments and future planning priorities can be informed. As seen in New Orleans, damages and loss of life are directly tied to depth of flooding, which in turn was inversely tied to the elevation of the location or subbasin.

- During Katrina, infrastructure and business damages were much larger than what had been estimated previously. The linkages necessary for a healthy business community were destroyed. Even at the residential level, damages as they relate to the cost of repairing and/or replacing houses were much greater when large segments of the population suffered the damages, and where the business and community infrastructure were also destroyed. It should be noted that the economic analysis as currently practiced does not account for these effects.

Other reports, such as the American Society of Civil Engineers' (ASCE) External Review Panel report (June 2007), *The New Orleans Hurricane Protection System, What Went Wrong and Why*, also addressed the issue of organizational impacts. No single agency or organization was ultimately responsible for the New Orleans Hurricane Protection System. No single entity or coalition of entities was providing systemwide oversight and focus on critical life safety issues. The U.S. Army Corps of Engineers could not implement improvements to the system without local board approval, and proposed changes such as providing protection along Lake Pontchartrain instead of along the canals after Hurricane Betsy, were met with resistance and ultimately abandoned.

As seen in New Orleans, damages and loss of life are directly tied to depth of flooding.

6 Considerations for Sound Flood Risk Management

The state must identify those locations where the depth of flooding could pose a significant threat, and where there are people, property, and infrastructure subject to the threat now and in the future.

Action is needed now to address the threat of flooding in California's Central Valley. In carrying out needed actions, Federal, state and local governments should consider the following:

a. Realistic assessment of the risk faced by those in the floodplain.

Accurate and rapid delineation and mapping of the natural floodplain (the ancient floodplain) in general and deep floodplain areas in particular is essential. The state, together with federal and local governments must identify those locations where the depth of flooding could pose a significant threat, and where there are people, property, and infrastructure subject to the threat now and in the future. Mapping the distribution of risk is altogether different than mapping the flood (i.e., the National Flood Insurance Program maps the 100-year flood). Mapping the risk includes both sides of the risk equation—the probability of flooding and the current and future consequences of that flooding.

Equally important is the identification of areas having the least risk of flooding to provide a focus for sustainable development and locations for growth, and to support the evacuation of high-risk areas. Areas that have a high probability of flooding but have low consequences should be identified so that future development in those areas does not increase the risk (by increasing the consequences of a flood, should one occur).

The probabilities of the occurrence of various failure mechanisms—collapse, system malfunction, and seismicity—in addition to the risk of overtopping in an event larger than the levee was designed for must also be determined as accurately as possible, so that residual risk can be mapped across each basin.

Reasonably high-resolution maps of estimated potential flood depths are also important to sound development in floodplains that may not be mapped by the National Flood Insurance Program if the levees become or continue to be certified as providing protection.

b. A comprehensive approach to water management and related land-use.

In dealing with the flood threat, California must develop comprehensive basin-wide plans for flood risk reduction in the

Sacramento and San Joaquin Basins. This will facilitate flood damage reduction efforts to be carried out on a basin-wide basis that reflects the interactions among all current and proposed flood damage reduction projects, planned development, other water management activities (water quality, water supply, navigation, and the like), and the requirements for restoration of natural and beneficial functions in the floodplains. (A detailed discussion of comprehensive planning is presented in Appendix C.)

Based on iterative and successively higher-resolution basin plans, the state and responsible agencies must take immediate action to deal with the most serious structural deficiencies and work over time to deal with longer-term issues. Local governments need to prepare and adopt floodplain management elements of their state-required General Plans that recognize the realistic potential for future urban development in flood hazard areas and plan accordingly to limit risk through land-use regulations and building codes.[38] In order to do this effectively, local governments will have to know what the risks are and govern accordingly.

The Panel understands that development is an essential part of meeting future social and economic needs of the region and the state. Understanding the relative risks of development by area will provide the knowledge to focus development in areas best suited for it and create the least risk now and in the future for property owners, the community, and taxpayers. It is also necessary to examine patterns and concepts for development that are most compatible with the social/economic needs of the area, best exploit the character and capacities of the environment and existing surrounds, and maximize the benefits, security, and sustainability of these areas for the long term. This, coupled with regulations that permit safe development (development that is wet or dry floodproofed and otherwise designed to not have adverse consequences when flooded) in the highest-risk zones will dramatically enhance the long-term viability of the region and reduce the burdens imposed by imprudent development.

Understanding the relative risks of development by area will provide the knowledge to focus development in areas best suited for it and create the least risk now and in the future for property owners, the community, and taxpayers.

c. Anticipation of and protection against future conditions.

Climate change, population growth, subsidence, urban and

[38] California recently enacted legislation that would require the land use element to identify and annually review those areas covered by the general plan that are subject to flooding as identified by floodplain mapping prepared by FEMA or DWR. The bill also would require, upon the next revision of the housing element, on or after January 1, 2009, the conservation element of the general plan to identify rivers, creeks, streams, flood corridors, riparian habitat, and land that may accommodate floodwater for purposes of groundwater recharge and stormwater management.

As part of comprehensive planning, there must be an identification of critical areas requiring restoration and /or enhancement.

upstream development, and changes in land use, channel conditions, and the condition of flood control structures could result in a significant increase in the risks (both the probabilities and the consequences of flooding) to certain areas. Planning and project decisions and calculations of risks must take into account these possible changes. This is already happening in other areas of the country—levees currently being restored and/or constructed in New Orleans are designed with full consideration of probable sea level rise and subsidence over the next 50 years. Changes in land use (either planned or projected) as well as changes in hazard conditions should also be anticipated and considered. Both the hazard and potential consequences of the hazard can change over time and need to be considered in formulating an adequate approach. This requires the need for modular improvements, and robust, "no-regret" measures and designs, like levees that can withstand overtopping or can be raised later at low costs.

Dealing with future floods will also require the use of the best and most innovative tools available. This includes the use of state-of-the-art technology to develop "smart" levees and flood control systems that will enable more control over water management systems during a flood and allow the possibility to act, for instance when sensors indicate the probability of a levee breach or an overtopping. These tools are available or under development right now.

d. Protection, enhancement, and restoration of the badly damaged natural and beneficial functions of the floodplain and watershed.

Construction of the flood infrastructure in the Central Valley has significantly altered the natural and beneficial functions of the floodplain and future flood damage reduction efforts must reflect attention to the restoration and enhancement of natural functions. In addition to mitigating for the environmental impacts of flood infrastructure, floodplain restoration can reduce flood heights and velocities, thereby reducing flood risk.

Therefore, as part of comprehensive planning, there must be an identification of critical areas requiring restoration and/or enhancement. Basic environmental needs should be identified and efforts made to meet those needs concurrent with the development of flood damage reduction projects. In some cases, the goals of floodplain restoration and flood damage reduction can be accomplished simultaneously through multipurpose setback levees and bypasses which can provide the benefits of habitat, floodwater storage and conveyance, and community open space. The

Sacramento River Yolo Bypass demonstrates that flood storage and conveyance can be consistent with both productive agriculture and high-quality habitat for fish and birds. Attention must also be given to methods to keep open areas open over time, such as public acquisition, transfer of density to flood-free sites, and low-density zoning.

Integrating flood damage reduction with ecosystem restoration (at both project and planning levels) not only contributes to generalized environmental needs but contributes directly to specific ecosystem restoration goals of the state and federal governments (e.g., CALFED, endangered species recovery). By helping to achieve these goals, floodplain restoration can help improve the operational flexibility of the California water management system.

State bond funding for floodplain management should reward programs that combine flood damage reduction with the protection of the beneficial benefits of floodplains including water quality and supply, environmental habitat, agriculture, and recreation. Including ecosystem restoration, recreation, and protection of working farms also broadens public support for local flood management projects.

e. Clear definition of the responsibilities at federal, state, and local government levels.

Specific responsibilities and liabilities must be assigned to those who control water resources and land development to make sure that they are accountable for their actions and the consequences of those actions. The state and federal agencies should provide accurate risk information to local governments, rules and incentives for acceptable local actions relating to floodplain development, and standards for construction and land use in the floodplain.

As with state laws regarding the housing element of local government General Plans, there should be appropriate penalties for failure to comply with state rules for floodplain development. These might include conditioning state-funded levee improvements within jurisdictions on the preparation of an acceptable floodplain management element of the General Plan (and Emergency Action Plans) and certification of the adequacy of the element by the Department of Water Resources.

Periodic monitoring of local government implementation of policies and actions specified in the floodplain management element is also essential. Where benchmarks are not met or policies are disregarded, the state should be authorized to declare a moratorium on the issuance of building permits for construction in the floodplain until the problem is rectified.

Specific responsibilities and liabilities must be assigned to those who control water resources and land development to make sure that they are accountable for their actions and the consequences of those actions.

The Panel recommends that mandatory flood insurance be required for properties in the FEMA 500-year floodplain and for those behind levees, even if the levee reaches Standard Project Flood protection.

Should the state contemplate these actions, the Governor should appoint a Central Valley Flood Risk Reduction Task Force comprised of local elected officials, developers, and environmental stakeholders to recommend the most feasible approaches for implementation that is phased over time.[39]

f. Continuous monitoring, assessment, and reporting on flood infrastructure conditions.

The strength of levees and of the system as a whole must be known. The higher the risk, the greater the need for continuous monitoring of what is changing, assessment of the underlying conditions, reporting (letting responsible officials and citizens at risk know what is happening so they may react), and risk communication (informing the taxpayers funding the flood control structure, and those living and working in protected areas of their risks).

Provisions must be made for the employment of high-tech monitoring through remote sensors or periodic remote assessment. California should focus on and invest in new monitoring technologies and methods, geotechnical investigations, failure tests, and regular safety inspections. If conditions are monitored during a flood or a period of high water, then evacuation plans that are triggered by certain water levels can be better coordinated. Assessment also supports the development of information on which to base the construction of fragility curves for use in the development of joint probabilities of failure.

g. Attention to residual risk.

Responsibility for dealing with residual risk behind levees and other flood control structures should be addressed comprehensively. Financial exposure to loss should be met by those at risk through use of mandatory insurance at rates that reflect the level of the residual risk (as opposed to a fixed standard). To avoid a potential crisis for the California economy and to facilitate recovery and reconstruction by those afflicted by levee failure, the Panel recommends that mandatory flood insurance be required for areas at risk for when levees do not successfully protect from flooding. Such a requirement would also help avoid costly and inefficient

[39]California recently enacted legislation imposing restrictions on development unless significant progress is made towards a 200-year level of flood protection for urban areas. While it does not go into effect for enforcement until 2015 and therefore is not as timely as the Panel would like, it is at least a step in the right direction.

litigation as well as potential exposure of the state and local government to liability. If the federal government does not move in this direction, the state must create insurance requirements beyond those of the National Flood Insurance Program. In order to ensure more complete coverage, consideration should be given to the alternatives outlined in the report commissioned by the Department of Water Resources entitled, *Alternatives for Increasing Flood Insurance Participating for Communities behind Levees in California.*

Howard Kunreuther, co-director of the Risk Management and Decision Processes Center and professor at the Wharton School of the University of Pennsylvania, notes that a new approach to indemnification is necessary that would encourage individuals to undertake mitigation measures to reduce their risk. He asserts that premiums should be risk-based, and that low-income citizens should be afforded publicly-funded vouchers for partial reimbursement for high premiums. Risk-based premiums would provide a, "clear signal of relative risk to those living in areas subject to natural disasters," and it would allow insurers to give discounts to individuals that undertake measures to reduce their risk. A publicly-funded voucher system for low-income individuals would imply that society as a whole should have an interest in hazard mitigation and indemnification. This type of system would also encourage low-income residents to invest in mitigation to lower their rates as well.[40]

In addition to mandatory insurance behind levees and in the FEMA 500-year floodplains, the state should examine new methods of mitigating financial losses from flooding to help facilitate a structured, organized, and planned rebuilding process including planning for evacuation, housing refugees, rebuilding, and planned long-term recovery. Post-disaster plans should be prepared that address the need for sheltering displaced populations, restoring damaged infrastructure, and rebuilding in ways that reduce future exposure to flood damages.

In addition to mandatory insurance behind levees and in other at-risk areas, the state should examine new methods of indemnification to facilitate a structured, organized, and planned rebuilding process including planning for evacuation, housing refugees, rebuilding, and planned long-term recovery.

h. Continuous re-evaluation of the operation of water management structures.

Escalating flood risk coupled with foreseeable climate change scenarios will lead to increased demands on water management structures that are already taxed to meet multiple water resource and environmental demands. The state along with its federal and local partners should evaluate how adjustments in managing

[40] Howard Kunreuther, *Who Will Pay for the Next Hurricane*? New York Times Op-Ed, August 25, 2007.

The strength of a levee is at least as important as its height. The levee of the future is stronger, is armored on the backside, and has a storage area behind it that will allow for some overtopping

downstream flood risk might result in increased flexibility within existing structures for non-flood demands. Likewise, it is advisable to continue to seek efficiency in operation while recognizing the various demands placed on these structures to meet a variety of needs including flood protection. Changes can be made by federal, state, and local governments in the operation of existing facilities to meet these objectives. Re-evaluation of operating rules should consider tradeoffs among flood, hydropower, agricultural, recreation, ecosystem maintenance and restoration, and M&I storage with a view towards possible compensated re-operation where such actions are justified.

i. Consideration of agility and redundancy in flood damage reduction planning.

Levees should be designed or modified to deal with the threat of overtopping and the land behind levees should be regulated in accordance with the possibilities of flooding.[41] For example, armoring the land side of levees, constructing weir or low-point spillway levee sections,[42] accounting for subsidence, and adjusting for design flows that take climate change into consideration would all require upgrades or changes to the system.

The strength of a levee is at least as important as its height. A robust and strong levee that can withstand a certain overtopping for a certain period of time is probably safer then a levee that is designed not to be overtopped, but only to prevent from overtopping. The levee of the future is stronger, is armored on the backside, and has a storage area behind that that will allow for some overtopping.

The system must be agile—able to change when the need arises. Changes in the system should not be feared but planned for. Where feasible, the current levee should be left in place and a stronger setback levee built behind it. This not only provides the opportunity to properly design and build the new levee, but in many areas, could allow removal of the old levee on the bank of the river.

Setting back the levee in this manner not only allows the enhancement of the natural and beneficial functions of the floodplain, but the widened floodway also allows for greater storage of floodwaters, potentially reducing flood stages in other parts of the

[41] When levees overtop they are subject to erosion and subsequent failure (breaches).

[42] Use of weirs and spillways at the downstream end of the levees section focuses any failures in a clearly defined area that can be properly prepared for such an event. Knowing where the overtopping is going to take place permits floodplain managers and emergency responders to make definitive plans for that circumstance.

system. Identify and assure that the stream of funding necessary is in place to adequately monitor, assess, maintain, and upgrade infrastructure as needed.

The public must know the nature of the threat and what it can do to mitigate the consequences should flooding occur.

j. Continuous enhancement of emergency evacuation and response planning and preparation.

California must have an effective emergency response capability. Recognize that, sooner or later, a catastrophic flood event will in fact happen. Part of the risk (the consequences) can be mitigated by effective warning systems and evacuation plans. Improved transfer of information between state and local agencies is critical. Most importantly, local agencies need to be contacted to determine how and what information will best support their emergency response activities at all levels of flow. Emergency planning for areas behind levees should be tied to forecasts and possible mandatory evacuations at certain "trigger" water heights, with annual notification to property owners of the plan and of their evacuation routes.

There should be two sets of plans—one that responds to the situation in which it has been forecasted that the water will reach the top of the levee in some certain time period (tomorrow); and another, wholly different plan for notification and evacuation that is triggered when a levee fails before the water reaches that height.

k. Enhancing what the public knows and understands about the flood risk it faces.

Effective education significantly enhances public support and action. The public must know the nature of the threat and what it can do to mitigate the consequences should flooding occur. Where residual risk is clearly defined, residents will make more informed and better decisions.[43]

Because "risk" includes a measure of both the probability of flooding and the consequences of that flooding, the risk will be different at different sites depending on the consequences. Likewise, changes in the hazard, the reliability of the data used to assess the hazard, the reliability of the flood protection structures, and changes in the consequences of a flooding event will all affect the risk in an area. This may be a difficult concept for the public to understand if they don't first understand the definition of risk.

To be most effective, information about risk should be accompanied

[43] California recently enacted legislation that would require DWR to provide yearly written notice to each landowner whose property is determined to be within a levee flood protection zone.

by information about what households and businesses can do to reduce risk to acceptable levels, such as purchasing flood insurance or retrofitting buildings so that these buildings are less susceptible to damage.

I. Economic incentives for Multi-Objective Management (M-O-M) of deep floodplains in the Central Valley.

State funding for Floodplain Management should reward programs that combine flood damage reduction with the protection of the beneficial benefits of floodplains including water quality and supply, environmental habitat, agriculture, and recreation. Including ecosystem restoration, recreation, and protection of working farms also broadens public support for local flood management projects.

7 Recommendations

To deal with these flood problems, the state and local governments, in coordination and with the support of the federal government must carry out the actions listed below. These actions should be treated as an integrated package and not as independent efforts as the success of one action is dependent on the success of the others.

- Provide the highest level of risk reduction feasible to existing urban areas where thousands of people are at unacceptably high risk. The Panel believes that this level of protection should be equivalent to protection against the Standard Project Flood, which represents a flood that can be expected from the *most severe* combination of meteorologic and hydrologic conditions that are considered *reasonably characteristic* of the region. Providing this level of protection does not, by itself, prevent the failure of the system or of individual levees; nor does it guarantee that the Standard Project Flood cannot be exceeded in rare circumstances.[44] One hundred year protection is not an acceptable level of protection for urban areas.
- Develop an implementation plan for providing this reasonably high level of protection for all urban areas. The needed level of flood protection should be phased in with at least a 200-year level of flood protection to be achieved by 2020, and Standard Project Flood protection by 2030. Priority should be given to urban areas in deep floodplains.[45]
- In less populated areas, provide for protection against less severe floods (e.g. less than 200-year protection) as economically and environmentally justified, and maintain that lower level of protection into the future.

Provide Standard Project Flood protection for urban areas. This level of protection does not, by itself, prevent the failure of the system or of individual levees; nor does it guarantee that the Standard Project Flood cannot be exceeded in rare circumstances.

[44] Since it is based on estimates of typical meteorological events, the SPF is not associated with a specific return interval (as is the 100-year flood). It is, however, in the Central Valley watersheds generally considered to fall within the 200- and 500-year return period as developed using national computation methods.

[45] Private development of levees should be limited to those cases where the construction meets national levee standards, the project is in conformance with the state's comprehensive plan for flood damage reduction, and a public agency agrees to provide long-term maintenance of the levee.

Require mandatory flood insurance for those behind all levees and those in the non-leveed FEMA 500-year floodplain.

- Ensure that any flood protection provided is sustainable fiscally and physically over time.
- Manage the floodplain by focusing new development outside of the floodplain or in low-risk locations within protected areas of the floodplain, supporting the use of undeveloped and unprotected land for agriculture and other low-intensity land uses.[46] Floodplain management should be accompanied by requirements for local governments to adopt *and enforce* needed land-use controls, financial and technical support to enable them to do so, and appropriate penalties if local governments fail to manage development to reduce flood risk. The state should continue to support the Federal Emergency Management Agency's levee policy and assist them in accelerating completion and adoption of updated flood maps. This would ensure that any new development in areas behind inadequate levees takes place under the land-use provisions mandated by the National Flood Insurance Program, as a minimum.
- Site, where feasible, new levees or major rehabilitation of levees at a distance from the river and from existing levees. This would provide a degree of redundancy in the system, increase the land available for habitat and flood storage, reduce operation and maintenance costs, and help to ensure the integrity of the structures. Levees built this decade will be in place for decades to come, and now is the time to begin building structures that will last. Where re-siting is not feasible, the existing flood system should be modified to mitigate the impacts of floods that exceed the design level of the system.
- Mitigate potential financial losses to those behind levees and to those in the non-leveed 500-year floodplain shown on Federal Emergency Management Agency flood maps[47] through institution of mandatory purchase of flood insurance, or through inclusion of

[46] California recently enacted legislation imposing restrictions on development unless significant progress is made towards a 200-year level of flood protection for urban areas. While it does not go into effect for enforcement until 2015 and therefore is not as timely as the Panel would like, it is at least a step in the right direction.

[47] Careful attention will have to be paid in FEMA's remapping of Central Valley floodplains to ensure that the extent of the 500-year floodplain is calculated using techniques that accurately reflect the situation in the Central Valley.

flood insurance in homeowners' policies of those within these areas. Insurance should be mandatory behind all levees, whether they have reached Standard Project Flood levels of protection or not.

- Share the liability for flood damages among state and local governments. This would ensure that any local governments making land-use decisions that could increase potential flood damages share not only the benefits of that development, but also any liability incurred from potential flood consequences should those decisions prove to have been unwise.[48]
- Communicate to the public and each property owner in the floodplain the specific risks of occupying areas at risk of flooding, and provide steps property owners can take to reduce their exposure to flood damages.[49]
- Work together with the development, environmental, and business communities, and with citizens. Outreach and coordination with these groups is vital to the success of any floodplain management program for the Central Valley. Consider formation of a Task Force comprised of local elected officials, developers, and environmental stakeholders to work with the state to develop an acceptable approach to implement these recommendations over the most expedient timeframe possible.
- Supplement the structural protection provided with floodproofing, elevation of homes and businesses, land-use regulations, and other non-structural approaches to reduce the residual risk that will continue to exist. Support this with emergency response systems including the development of post-disaster sheltering and redevelopment plans and the exercising of floodplain evacuation plans on a regular basis. Coupled with mandatory insurance and emergency preparedness, floodplain development and land-use standards beyond the minimum standards of the National Flood Insurance Program are necessary. Programs could be based on the

Coupled with mandatory insurance and emergency preparedness, floodplain development and land-use standards beyond the minimum standards of the National Flood Insurance Program are necessary.

[48] California recently enacted legislation to hold local governments financially liable if they unreasonably approve new development in floodprone areas.

[49] California recently enacted legislation that would require DWR to provide yearly written notice to each landowner whose property is determined to be within a levee flood protection zone.

Coupled with mandatory insurance and emergency preparedness, floodplain development and land-use standards beyond the minimum standards of the National Flood Insurance Program are necessary.

development status of the region (developed versus undeveloped), or be based on new floodplain characterizations ("zones") that take the results of levee stability assessments into account and would go beyond those of the Federal Emergency Management Agency's mapping program. Special attention should be paid to areas that are subject to particularly catastrophic sudden life-threatening flooding (i.e. very deep floodplains, levee breaks, and reasonably likely unregulated flows from dams).

Dealing with flooding in the Central Valley will require a close examination of existing governmental institutions and how they work together. The lessons learned from the New Orleans disaster point out the disconnects that develop when too many agencies are involved in the decision-making process and no one agency has overall direction. Large flood events exploit those disconnects. California must address this difficult issue, especially in terms of the large number of overlapping roles, responsibilities and accountabilities of reclamation districts, and state and local governments. Without reforming the institutions that manage flood control, large investments in infrastructure are likely to be wasted.

The above recommendations reflect a system approach to dealing with the Central Valley flood threat. As work progresses, each action must be weighed against the long-term economic, engineering, environmental, and social costs and benefits of the action under consideration. What is developed over the next decades for flood protection in the Central Valley may well be the system that will carry the Valley into the next century. What is done must be done correctly.

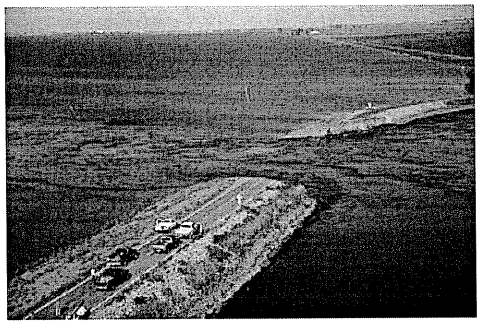
8 Implications for the Remainder of the State

The Panel recognizes that floodplain delineation, mapping, hazard planning, and communication are just as important for the rest of the state as they are for the Central Valley. Indeed, other areas of the state may not have the specific issues associated with the type of deep flooding that can occur in the Central Valley, but significant damages can occur even from flood depths of one to five feet, and these damages are easiest to prevent if communities regulate building techniques in these areas.

The Delta, Southern California, and other areas of the state have significant flood problems as well. The strategies outlined here can be exported to the rest of the state.

The strategies outlined here can be exported to the rest of the state as well. The ideas are simple:

- Understand the risk now and in the future;
- Develop a systems-based understanding of water management and everything associated with it (environmental conditions and concerns, etc.); and then
- Plan for it—now and in the future.
- Avoid, to the maximum extent possible, putting people who are not presently at risk in flood hazard areas.
- Make sure that what is built is appropriate for the risk and is maintained to meet the ever-changing threat.



Photos courtesy of California Department of water Resources

FEMA News Photo 1311/Dave Gatley

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Appendices

Appendix A: Biographical Sketches
Panel Members, Consultants and Technical Support Personnel

Dr. John J. Boland, PE

Dr. John Boland is an engineer and an economist, specializing in water and energy resources, environmental economics, and public utility management. He is currently Professor Emeritus at the Johns Hopkins University, after more than thirty years in the Department of Geography and Environmental Engineering. Dr. Boland has been a consultant to numerous utilities and government agencies throughout the world as well as a number of international agencies. He has served on many committees and panels of the National Research Council, including one term as chairman of the NRC's Water Science and Technology Board. He is a Lifetime National Associate of the National Academies and a member of U.S. EPA's Environmental Financial Advisory Board.

Dr. Raymond J. Burby

Dr. Raymond Burby is a professor emeritus at the University of North Carolina at Chapel Hill in the Department of City and Regional Planning. Formerly the Assistant Director for Research at the UNC Center for Urban and Regional Studies, Professor in the Department of City and Regional Planning at UNC, John M. DeBlois Chair in Urban and Public Affairs at the University of New Orleans, Distinguished Professor of Urban and Regional Planning at the University of New Orleans, and a Fulbright Senior Scholar at the School of Town Planning at the University of New South Wales, Australia. He holds a Bachelors of Arts in Government from the George Washington University, a Masters or Regional Planning from the University of North Carolina, Chapel Hill, and a Doctorate in Planning from the University of North Carolina, Chapel Hill.

Joseph D. Countryman, PE, D. WRE

Joseph D. Countryman has over 40 years of experience in planning, designing and operating flood control facilities in California. He worked for the Corps of Engineers for 21 years and headed up their reservoir operations branch and reached the level of Chief of Civil Design in the Sacramento District. He has been with MBK Engineers for the last 20 years and is currently President of the company. He has provided flood control expertise to public agencies from Fresno to Yuba City and has been a primary consultant to the Sacramento Flood Control Agency.

Michael DePue, PE, CFM

Mr. DePue is an Associate Vice President with PBS&J's Floodplain Hazards Management Group. Mr. DePue received an M.S. in Hydrosystems Engineering from the University of Illinois at Urbana-Champaign and a B.S. in Civil Engineering from Clemson University, and has been with PBS&J since 1996. Mr. DePue's experience includes management of countywide Digital Flood Insurance Rate Map (DFIRM) production, review of Letters of Map Change, levee policy, technical and database review, and flood mapping operational and business planning. Mr. DePue is author or co-author of fourteen papers on flood modeling and has taught several dozen courses and seminars on FEMA flood mapping. He is a registered professional engineer in twelve states and a Certified Floodplain Manager as well as a Diplomate, Water Resources Engineer (D.WRE).

Piet T.M. Dircke Msc

Piet Dircke is Program Director of the Water Division of ARCADIS Netherlands. He is coordinator of the ARCADIS water activities worldwide, with emphasis on the U.S. He is involved in innovations in flood control, levee design, restoration and monitoring, and integrated river and water management. He is responsible for the transfer of Dutch flood control expertise to the ARCADIS $150 million IDIQ contract with the U.S. Army Corps of Engineers for restoration of the Hurricane Protection System of New Orleans. He was an official member of three delegations representing the Netherlands Water Sector to California in 2006 and 2007. He was recently appointed as a Professor for Urban Water Management at the University of Rotterdam, The Netherlands. He studied at the Wageningen University and Research Centre and worked for the Municipality of Amsterdam, for a water board and for a Province before joining ARCADIS.

Dr. Gerald E. Galloway Jr., PE

Dr. Gerald E. Galloway, Jr. is a Professor of Engineering and Affiliate Professor of Public Policy at the University of Maryland. He is also a consultant to the Michael Baker Corporation for the FEMA Flood Map Modernization and recently chaired the Interagency Levee Policy Review Team for FEMA. He was a Presidential appointee to the Mississippi River Commission and in 1993-1994, led a White House study of the causes of the 1993 Mississippi River Flood. During a 38-year career in the military, he served in various assignments in the U.S. and overseas, retiring in 1995 as a brigadier general and Dean of Academics at the U.S. Military Academy. He is a member of the National Academy of Engineering.

Christopher B. Groves, PE

Chris Groves, PE, has 35 years experience as a geotechnical engineer. His responsibilities include planning and monitoring subsurface exploration programs; siting studies; and analysis, design, and instrumentation of foundations, earth dams, excavations, and earth retaining structures. He has served on Independent Technical Review (ITR) teams, performed value engineering studies, and provided expert geotechnical consultation for large dams and levees. He is currently participating on the ITR team that is evaluating 300 miles of urban levees in Sacramento. He participated in a Task Force to evaluate the USACE Sacramento District practices in analysis and design of levee underseepage control measures. He performed a complete review and re-assessment of the geotechnical features of a proposed urban levee to be constructed by the USACE Saint Louis District to preserve historical Sainte Genevieve, MO.

William Hinsley, PE

Bill Hinsley is an Associate Vice-President and Senior Project Director with PBS&J. For the past ten years, Mr. Hinsley has focused on developing the Everglades and Louisiana Coastal Area ecosystem restoration efforts. Following Hurricane Katrina, Mr. Hinsley led PBS&J's support to the U.S. Army Corps of Engineers and Louisiana State recovery and rebuilding efforts. He is currently focused on bringing experience from these programs to the floodSAFE California, California Bay-Delta, and Puget Sound Nearshore Ecosystem Restoration programs. Mr. Hinsley has a Bachelor of Science in Biology from Wake Forest University and a Masters Degree in Marine Affairs and Policy from the University of Miami. He is a fellow of the Florida Natural Resources Leadership Institute and serves on numerous boards.

Larry Larson, PE, CFM

Larry Larson is Executive Director Association of State Floodplain Managers and is one of the nation's foremost experts on flood hazards and water resources management. He coordinates national flood policy development and advancement. He also oversees the association's activities and communication with state and federal agencies, the Administration, and other policy groups and organizations. Larson's entire 40 plus year career has been devoted to flood hazard and water resources management. He is the co-developer of ASFPM's No Adverse Impact approach to community development and has authored numerous white papers and articles. He frequently provides expert testimony and speaks to scores of policy makers, floodplain managers and related groups, both nationally and abroad. Larson holds a Bachelor of Science degree in civil engineering from the University of Wisconsin and is a registered professional engineer in Wisconsin and California.

Hon. Susan Lien Longville

Dr. Susan Lien Longville is the Director of the Water Resources Institute (WRI) at California State University-San Bernardino, an interdisciplinary center that conducts research and analysis and provides educational assistance on water issues. Her background also includes employment in the water industry and two terms on the City Council of San Bernardino. Susan represented the Southern California Association of Governments on DWR's Floodplain Management Task Force in 2002. The WRI has a partnership with DWR to develop a stakeholder-comprised Alluvial Fan Task Force. It is charged with addressing the flood hazards associated with the rapid rate of development on alluvial fans by developing a Model Ordinance with Land Use Guidelines for local adoption. Findings will be reported to the Legislature.

Dr. Lewis E. Link, Jr.

Dr. Lewis E. Link is on the faculty of the Department of Civil and Environmental Engineering, University of Maryland. He has been serving as the Director of the Interagency Performance Evaluation Task Force, a government-industry-academic group of experts investigating the performance of the Hurricane Protection System in New Orleans. He is also a senior advisor to Toffler Associates, a strategic futures advisory firm that serves industry and government. Dr. Link was formerly the Director of Research and Development and Chief Scientific Advisor for the U.S. Army Corps of Engineers. He has been honored by the President of the United States four times as a Meritorious and Distinguished Executive and was recently awarded the McGraw-Hill Engineering News-Record Award of Excellence for 2006.

Jennifer Marcy, CFM

Ms. Marcy is a Senior Scientist in PBS&J's Floodplain Hazards Management Division with six years of experience with FEMA's National Flood Insurance Program (NFIP). Some of her experiences within the NFIP include leading a Certified Floodplain Manager (CFM) training program for floodplain managers across the Nation; preparing FEMA correspondence to citizens, communities, and elected officials; evaluating Letter of Map Change cases; and working with FEMA and States on floodplain management outreach and public awareness of flood hazards, including levee and insurance issues.

Dr. Jeffrey F. Mount

Jeffrey Mount is Professor and former Chair of the Department of Geology at the University of California, Davis. He also holds the Schlemon Chair in Applied Geosciences, is a former member of the State Reclamation Board, served on the National Research Council Panel on the Klamath River and is a recipient of the 2005 Distinguished Scholarly Public Service Award, which recognizes his contributions on issues of public concern such as flood risk, watershed management, and river restoration. His projects include analysis of geomorphology of floodplains, floodplain response to non-structural flood management measures, development of new floodplain restoration methods, role of hydrologic and sedimentologic residence time in riverine ecosystem health, development of coupled hydrogeomorphic and ecosystem models for environmental monitoring.

Dr. Jeff Opperman

Dr. Jeff Opperman works for The Nature Conservancy's Global Freshwater Team where he focuses on floodplain restoration, reservoir reoperation, and ecologically sustainable hydropower. Prior to working for The Nature Conservancy, Jeff did post-doctoral research through a CALFED Science fellowship at the Center for Watershed Sciences at UC Davis. There, he studied how California native fish use floodplains and methods to identify ecologically functional floodplains in the Central Valley. He developed the floodplain conceptual model for the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) and is currently writing a white paper for CALFED on Central Valley floodplains. He received his Ph.D. in Ecosystem Science in 2002 from the University of California, Berkeley.

Doug Plasencia, PE, CFM

Mr. Plasencia is a specialist in floodplain and watershed management. His input on floodplain management policy and science has been requested by the National Academies of Sciences, Congress, and various federal agencies. He is the co-developer of the No Adverse Impact floodplain management strategy as well as was instrumental in integrating multi-objective planning strategies into floodplain management. He is past Chair of the Association of State Floodplain Managers and served on the FEMA Director's advisory board from 1994-1996. Doug is employed by Michael Baker Jr. Inc., where he serves as the Director of Water Resources for the Western United States.

Dr. Raymond B. Seed

Dr. Raymond Seed is a Professor of Civil Engineering at the University of California at Berkeley. A long-standing consultant to state and federal agencies on dams and levees, he led the NSF-sponsored independent investigation team in evaluation of the performance of the New Orleans regional flood protection systems during Hurricane Katrina. Dr. Seed currently serves on the Governor's Blue Ribbon Task Force for the Sacramento Delta, and as an advisor to the California Department of Water Resources Urban Levees Program.

George L. Sills, PE

George L. Sills is a Geotechnical Specialist/ Research Engineer at the U.S. Army Engineer Research and Development Center (ERDC) and has been employed by USACE for 36 years. During this time he has designed and inspected the construction of hundreds of miles of levees and participated in numerous major flood fights across the country. He is currently leading teams that are developing toolboxes for the Corps to use in performing Probabilistic Risk Assessments for piping and seepage failure modes for dams and levees and a team that is rewriting the Corps levee design manual. Mr. Sills was selected to serve on the Corps' Interagency Performance Evaluation Task Force (IPET) following Hurricane Katrina as a member of the Perishable Data Team and also as a member of the Performance Analysis Team. Prior to Katrina, Mr. Sills was a member of USACE Community of Practice (COP) for levees.

James J. Smyth, PE

James J. Smyth, founder of Smyth Water Planning Solutions, is the former Deputy Assistant Secretary of the Army for Project Planning and Review. In that position, he was the Army's principal technical and policy advisor regarding the planning, development and implementation of Corps of Engineers water resources projects. He has over 41 years experience in developing flood control, inland and coastal navigation, coastal hurricane and storm damage reduction, and ecosystem restoration projects and is a recognized expert in formulating, justifying, and evaluating projects. He has extensive experience working with non-Federal sponsors, Federal, state and local agencies, Congressional staff, and the Administration. From January 1981 through his retirement in June 2004, Mr. Smyth was involved in conducting independent and objective reviews of Corps projects, and in resolving policy, technical, planning, implementation, and legislative issues.

Ronald Stork

Ron Stork is Senior Policy Advocate for Friends of the River, Sacramento, California. For the last 15 years, Ron has had the principal responsibility for organizing Friends of the River's flood-management advocacy efforts in the American River watershed. Ron has worked on a number of Central Valley and California flood management issues, serving on the California Department of Water Resources' (DWR) California Floodplain Management Task Force, on working groups of the Corps/Reclamation Board Sacramento & San Joaquin Basins Comprehensive Study, and continues to serve on the interagency Yuba Feather Workgroup focusing on flood-management issues in this basin. Ron received his Bachelor of Science degree from the School of Agriculture at the University of California at Davis in Plant Science.

Edward A. Thomas, Esq.

Edward A. Thomas, Esq., is employed by the Michael Baker Engineering Corporation, working on the development of partnerships to better map natural and man-made hazards in the United States. He retired from the Department of Homeland Security-Federal Emergency Management Agency after nearly thirty-five years of Public Service. During his time in government, he worked primarily in Disaster Mitigation, Preparedness and Response. He also was involved in the construction and management of housing developments for the Department of Housing and Urban Development. Ed worked on about two hundred disasters and emergencies, serving as the President's on-scene representative, the Federal Coordinating Officer, dozens of times. Ed is an author, Attorney, and a frequent lecturer on emergency management issues, especially the constitutional and legal aspects of floodplain regulations.