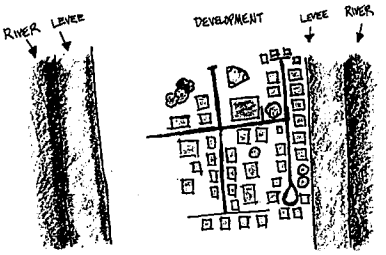
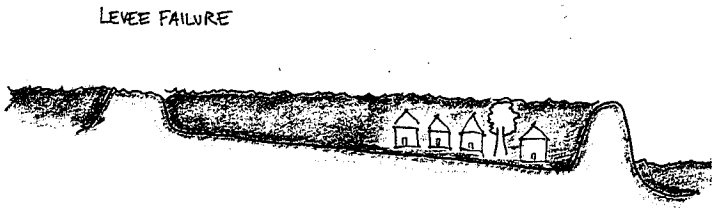
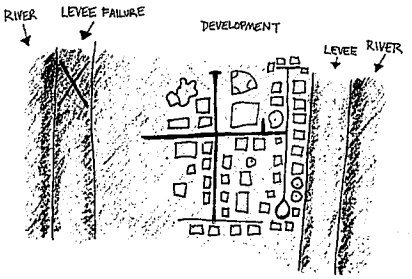
# Relief cuts as a flood management strategy

## Relief cuts reduce damage from flooding, especially when planned in advance.

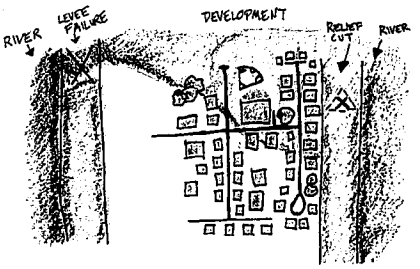
A relief cut is an intentional breach in the top of a downslope levee that releases water from an area flooded by an upslope levee breach. Cutting the downslope levee allows water to flow back to a lower elevation.






**Relief cuts are appropriate when:**

- The land to protect is on a gradient between a failed levee and a downslope levee
- There is an area of sufficient size to contain the water on the opposite side of the downslope levee

**Impacts:**

- Scouring and widening on either side of the cut
- Strong currents that lift up and move structures in the flow path (like houses)

**Proper Site Selection** minimizes the damage of these impacts; therefore **flood planning should include relief cuts and placement.** Development guidelines could include **relief cuts,** such as citing a park/open space on the opposite side of the cut.

Unfortunately, relief cuts are usually decided upon **last minute** due to **liability** concerns and **jurisdictional** conflicts that prevent reimbursement for the expense of making a cut.

To maximize the benefits and **reduce flood damage**, flood planning should include:

- Identifying the placement of relief cuts in advance of an emergency;
- Assigning responsibility (accompanied by funding) for making cuts;
- A plan for dealing with liability for damages caused by relief cuts.

Lindsey Fransen, Jessica Ludy, and Mary Matella. For full text see:
http://repositories.cdlib.org/wrca/hydrology/

# Don't Allow Further Building in Deep Floodplains

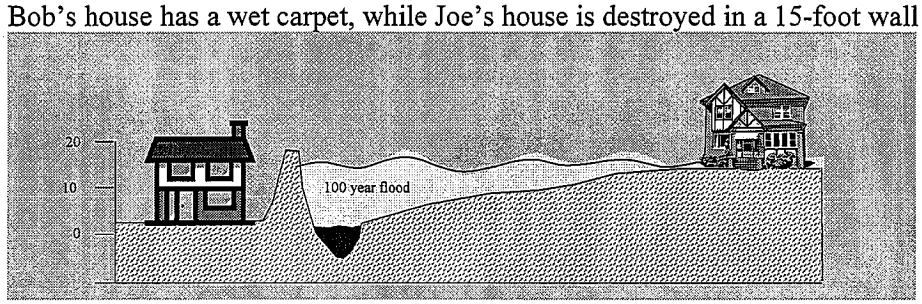
*Comments before the Delta Vision Task Force 18 Sept 2008*

Matt Kondolf, Professor of Environmental Planning, UC Berkeley
*http://landscape.ced.berkeley.edu/~delta/*

***Deep floodplains*** – lands below sea level or more than 10 ft below the level of the 100-y flood – are a bad place to build houses. This is hardly a new insight, and certainly one that was tragically illustrated in New Orleans three years ago this month. Nonetheless it bears repeating, lest we lose focus on this critical point. It matters not whether we call a place primary or secondary zone – developments in deep floodplains are doomed to flood, causing extensive damage.

***The One-Percent Approach*** Part of our problem is that we manage flooding using the 'one-percent approach', in which we map the extent of the 100-year flood – i.e, the flood with a 1 percent chance of occurring in any year. Calling it the "100-year flood" leads to widespread misunderstanding of the risk, with many assuming they are safe for 100 years, when in reality there is a 1 percent chance of having such a flood in any year.

More importantly, under the system of federal flood insurance, if an area is protected by a (100-year certified) levee, that area is no longer officially considered part of the floodplain. The silliness of this approach is illustrated by a cartoon showing two houses: On the right, the house of Bob is located within the mapped 100-year floodplain, but near its edge. During a 100-year flood, its living room carpet will get wet, but damage is limited. However, Bob is considered to be within the 100-year floodplain and may be required to buy flood insurance. By contrast, the house of Joe (to the left) is located within a deep floodplain, but it has been officially 'taken out' of the floodplain because it's protected by a 100-year-certified levee. The consequences of levee overtopping/failure are very different in the two places: Bob's house has a wet carpet, while Joe's house is destroyed in a 15-foot wall of water.




***Levee Failure is Inevitable*** As observed by William Hammond Hall a century ago, there are two kinds of levees: those that have failed, and those that will fail. Even if does not fail because of seismic shaking or other structural weakness, a levee certified for 100-year protection will not protect against larger floods, such at the 500-year flood. In a given year, The chance of a levee being overtopped by floods greater than its 100-year design flood is termed the *residual risk.* Over the 30-year life of a mortgage, there is a 26% chance of being flooded by floods greater than the 100-year flood against which you are protected. This assumes levees function as designed, and does not account for seismic risk, which could cause extensive failures. Building on deep floodplains, we will create our own 'Hurricane Katrina'.

***Risk*** We increase overall risk by putting development on deep floodplains instead of cornfields, even if we strengthen levees. If we are serious about reducing risk, we cannot put more houses in harm's way.

***Lost Restoration and Flood Bypass Opportunities*** By urbanizing deep floodplains, we forgo opportunities to restore wetlands and we lose flexibility in managing floods (e.g., bypasses). It may be impossible to achieve the co-equal goals of water supply and ecological restoration.

***No Development in Deep Floodplains!*** The Task Force's 'Vision' came out strongly against this kind of development, and that message should be strengthened in the Strategic Plan. There are other places we can build to accommodate increased population. We can and must avoid building in deep floodplains.

# When the levees break: Relief cuts and flood management in the Sacramento-San Joaquin Delta

## Hydrology for Planners LA 222

**Lindsey Fransen, Jessica Ludy, and Mary Matella**

FINAL DRAFT

May 16, 2008

**Abstract**

The Sacramento-San Joaquin Delta is one of California's most important geographic regions. It supports significant agricultural, urban, and ecological systems and delivers water to two-thirds of the state's population, but faces extremely high risks of disaster. Largely below sea level and supported by 1,100 miles of aging dikes and levees, the Delta system is subject to frequent flooding. Jurisdictional and financial disincentives to better flood planning prevent coordination that might otherwise reduce both costs and damages. This study highlights one possible flood mitigation technique called a relief cut, which is an intentional break in a downslope levee to allow water that has overtopped or breached an upslope levee to drain back into the river. This flood management technique is "smart" when located in appropriate areas so that floodwaters can be managed most efficiently and safely after a levee break.

We identify four key constraints and make four recommendations for flood management planning. The constraints are: 1) *Perception of flood risk* – The public believes that levees will protect them from all flood events; 2) *Perverse incentives* – For reclamation districts to finance levee maintenance and flood planning, they must encourage development in flood risk areas to collect assessment fees; 3) *Litigation threat* – Agencies remain vulnerable to litigation after a flood which is a disincentive for taking action because no one wants the blame; and 4) *Reimbursement uncertainty* – Historical flood accounts demonstrate local entities are not always reimbursed for their expenditures which discourages quick action during a flood. We recommend the following actions for agency officials to endorse and the public to support: 1) *Acknowledge that levees will fail and plan accordingly;* 2) *Explicitly plan for emergencies such as relief cuts before the flood occurs;* 3) *Support interagency cooperation*, and 4) *Apply Full Cost Recovery concept from the European Union Water Framework Directive.*

## Introduction

In 1983, California experienced nearly twice its average runoff statewide, with numerous and sustained high peak flows. At 7:45 AM on March 6, a section of the levee along the San Joaquin River failed and floodwaters coursed into River Junction in Reclamation District (RD) 2064. As water levels rose inside the flooded tract, local officials wanted to make a relief cut, an intentional break in a levee to let the water drain off the land back into the river. However, the Army Corps of Engineers objected to the plan and officials had to travel to Sacramento to obtain permission to make the levee cut. In the meantime, the floodwaters threatened to enter the adjacent district, RD 2075. Local officials finally obtained the necessary permission and made the relief cut at 3:00 PM. This action lowered the water levels in the River Junction tract, preventing flooding in RD 2075.

Why did so much time pass before district officials could act? Why wasn't the levee break planned for and agreed upon ahead of time? Unfortunately, this flood management scenario is common in California's Sacramento-San Joaquin Delta. This study addresses these questions and offers recommendations for flood planning in the Delta that allows for swift, decisive action to minimize flood damage.

The Sacramento-San Joaquin Delta is one of the most economically and ecologically important areas in California (Figure 1). The Delta supports significant agricultural, ecological, and urban uses, and provides drinking water to two-thirds of the state's population. Draining the American, Sacramento, and San Joaquin rivers, the Delta area consists of a series of islands, mostly below sea-level, protected by 1,100 miles of dikes and levees (DRMS 2008). Although the majority of the land is in agricultural use, some areas are developed and remain under pressure for further urban development (Eisenstein et al. 2007). The risk of catastrophic flooding

due to aging levees, seismic activity, land subsidence, climate change and sea level rise, threatens the human and ecological systems that rest precariously at this geographical crossroads so vital to the state.

Flooding in the Delta is both inevitable and costly. More than 160 levees have failed since 1900 (DRMS 2008) and the majority of existing levees were designed to protect to Federal Emergency Management Agency (FEMA) 100-year flood standards, defined as the flood that has a one percent chance of occurring in any given year. However, considering the flood risk from storms larger than the 100-year event, residents living in the Delta region face a 25 percent chance of flooding during the course of a 30-year mortgage (Eisenstein et al. 2007). Even in smaller storms, flooding can result from levee failure. Many of the Delta levees suffer from internal weakness due to poor construction or lack of maintenance (DWR 2005). The 1997 floods forced more than 120,000 Delta residents from their homes, and more than 55,000 were housed in 107 shelters, the largest such operation in California's history. In 2004 the Jones Tract levee break cost the state over $100 million for damages and recovery (DWR 2005).

Levee failure and flooding pose a threat to current and future development in the Delta. Towns like Stockton and Sacramento are at risk of losing property, infrastructure, and human life. In addition, flood protection, prevention, and recovery costs are high. Therefore, it is in the best interest of the region to adequately prepare for flood prevention, protection, and recovery.

Relying on levees alone in the Delta is a strategy similar to French reliance on the Maginot Line during World War II (Ron Baldwin, San Joaquin Office of Emergency Services, pers. comm. April 2008). This 550km barrier was designed to protect Northern France from German forces and was assumed to be impenetrable (Allcorn 2003). Believing that no backup plan was necessary, the French suffered losses in 1940 when the Germans bypassed the line and

invaded through Belgium. In the Delta, responsible agencies, legislators, and residents depend on the integrity of levees to protect them from floods and flood damage, and seldom have a backup plan. However, history tells us that we need a better strategy or at least a plan B. In 1880 William Hammond Hall, California's state engineer, observed that there were two kinds of levees: those that have failed and those that will fail.

When a levee fails, the most effective response might be to make a relief cut on another levee further downstream. Relief cuts provide an outlet for water to drain during a flood, minimizing the height of the floodwaters on the land between levees. Relief cuts, while effective in certain situations, are rarely if ever included in flood control planning or in development plans (Baldwin, pers. comm. 2008).

*Relief cuts: Function and criteria*

Making a relief cut at the lower end of an area protected by levees is an established method for lowering the depth of impounded water following the failure of a primary levee (Court of Appeal, 2004). A relief cut is an intentional breach in the top of a downslope levee that releases water from an area flooded by an upslope levee breach. Cutting the downslope levee lets water flow back into a river where water elevation is lower (Figure 2). Lowering the depth of the floodwater on the land between levees reduces flood damages and the total area flooded. The pressure from floodwaters on a levee downslope can be so great that a "natural relief cut" occurs when it collapses from the inside back out into the river.

Whether a relief cut occurs naturally or is made intentionally, there are consequences that accompany the release of water from a flooded area back into a river. First, the swiftly moving water will widen the cut as it flows through and over the opening. It will also scour the area on both sides of the cut levee (Figure 3). Additionally, the current created by water rushing down to

the lower level of the river will pick up and move objects in its path and is strong enough to sweep houses off of their foundations (Neudeck, pers. comm. 2008). An example of this occurred during a flood in RD 2064 in 1997, when, in addition to two deliberate relief cuts, a levee spontaneously failed at another site. This unintentional breach let water back into the San Joaquin River, lowering flood levels, but also destroying two homes in Cardoza Village (KSN Inc. 2006). Thus, relief cuts should be carefully sited to minimize peripheral damage.

Relief cuts are an effective strategy to minimize damages, costs, and health and safety risks. However, flood management plans rarely include relief cut locations or identify responsible parties, leading to last minute, potentially dangerous implementation. The goal of this study is to investigate why agencies do not plan for relief cuts, offer an alternative approach to flood protection and mitigation behind levees, and consider how the full cost recovery principle of the European Union Water Framework Directive could apply to flood management in the Delta.

## Methods

### *Literature Review*

To provide a historical and current context for understanding the Delta, we reviewed documents on levees, past floods, current and proposed legislation, and land use planning. This also included agency reports, Reclamation District meeting minutes, legal filings from court cases, and regional planning documents on the area's background and specific issues faced by Reclamation Districts. To understand how emergency response planners seek to improve flood planning in the Delta, we reviewed a recent Flood Response White Paper. We were not able to find any published literature explicitly addressing relief cuts and flood planning.

*Expert Interviews and Map Review*

To gain a clearer understanding of the technical aspects and context for relief cuts, we conducted expert interviews. We made two visits to San Joaquin County's Office of Emergency Services and spoke with Ron Baldwin, the Incident Commander. We learned how relief cuts function, suitable conditions, necessary criteria for their use, and how planners might include them in two different flood scenarios. We also inquired about jurisdiction, liability, and agency response, and we reviewed several of San Joaquin County's Flood Contingency Maps (Figure 4). Flood contingency maps are typically created by an engineering firm for parts of the county with special attention to levees, urban developments, infrastructure, reclamation district boundaries, and in some cases, historical levee breaks and relief cuts. The flood contingency maps also document the flood history of the area and present the flood emergency action plan. San Joaquin County is one of the first Delta Counties to include options for relief cut sites on these maps.

We also spoke with Chris Neudeck, an engineer with the firm of Kjeldson, Sinnock, and Neudeck, which works for thirty of the reclamation districts in San Joaquin County. Neudeck's firm is responsible for flood-fighting and making relief cuts. We asked Neudeck more specifically how relief cuts function and gathered information about expected river heights in a typical flood scenario with and without relief cuts. We examined flood contingency maps to gain an understanding of appropriate sites for future relief cuts and to estimate potential inundation height and extent for a hypothetical flooding scenario.

**Analysis**

We documented the purpose and function of a relief cut and identified agency roles and jurisdictions in flood planning, flood fighting, and flood recovery by researching the Delta Risk

Management Strategy and conducting expert interviews with Baldwin and Neudeck. We also identified strengths and shortcomings of the current system to see whether different approaches might yield better, safer, or less costly results. Lastly, through interviews and research, we gathered rough economic data on the costs of flood prevention (levee maintenance), flood-fighting, and flood recovery.

## Results and Discussion

*Considerations in siting relief cuts*

Relief cuts are not appropriate in all flooding conditions or in all locations along a levee. Several criteria determine whether and where a relief cut should be used. First, relief cuts are only useful when an upslope levee fails, flooding an area that has a gradient towards another levee, which can be breached to allow the water to flow back into the river at a lower level (Baldwin, pers. comm. 2008). Next, an area of sufficient size and depth on the other side of the levee is necessary to receive and slow the water as it comes through the cut. A relief cut should not be made on a levee where there is only a narrow channel bordered by a levee on the other side, since the water could easily overtop the next levee and flood an adjacent parcel.

Other necessary features for a relief cut include an access road to the levee cut site and the absence of houses and other obstructions that would prevent heavy machinery from reaching and operating at the site. Because an opening will widen beyond the initial cut, the area of the levee on either side of the cut must be free of obstructions. Additionally, both sides of the levee near the cut site should be free of valuable or potentially dangerous infrastructure below ground that might be affected by scour, such as gas and sewer pipelines and telecom wires (Baldwin, pers. comm. 2008). Because the water may pick up objects in its path and transport them from

one side of the levee to the other, the location of houses and other infrastructure should be considered when siting relief cuts; conversely, the possible need to make a relief cut is something to consider when planning development.

*Scenarios*

Weston Ranch is a suburban development at the northern end of RD 17 in San Joaquin County (Figure 5). The San Joaquin River borders it on the west, flowing from south to north. In the event of a levee breach south of the development (Figure 5, point A), the water would flow downslope to the north, pooling against the levee from the inside (Figure 5, point B). Without a relief cut, the water could rise to the levee's height of 18.5 feet (reaching the second story of most houses), allowing water to inundate roughly 150,000 acres (Figure 6). Meanwhile, the river downstream could be expected to be at a level of twelve feet. If a relief cut were made in the downstream levee, water would drain out until it reached twelve feet – the height of the river – reducing the area of flooding to 80,000 acres and lowering flood heights by over six feet (Figure 6).

The three factors listed above drive the relief cut placement in the Weston Ranch scenario. First, a relief cut is most effective when at the lowest point on the downstream levee, in this case any point on the northern-most end of the development. Next, the open field (Figure 5, point C) on the outside of the levee is suitable for receiving and slowing floodwaters before they reach the other levee on the opposite bank of the river. Without sufficient area to receive the water released by the relief cut, the current could overtop the levee on the opposite bank and cause flooding there. Third, the site should be clear of obstructions such as water, sewer, or gas pipelines or telephone wires. The City of Stockton's sewer pipes run under the middle of the northern end of the District (Figure 5, D). To avoid this area, a relief cut should be made to the

west of these pipes (Figure 5, point E). The site is still not ideal because houses are built right up to the levee's edge, increasing their risk of damage from water currents and heavy machinery used on the levee. Nonetheless, this scenario is fairly straightforward, and the relief cut is currently included in the flood contingency map for the area (Figure 4).

Even without suburban development, siting and completing a relief cut is complicated. In 1950, a District levee failed in this area, flooding the northern end of RD 17 within nine hours and then backing up toward higher ground. Completion of a relief cut near what is now Weston Ranch was delayed for several days due to the City of Stockton's concerns over potential impact on the levees of RD 404. Once a cut was made, waters receded, but some houses were already flooded one to two feet. Interviewees indicated that completing the relief cut sooner would have reduced this level (KSN Inc. 2006).

Another scenario where competing interests make planning for relief cuts complicated is in RD 1614 (Figure 7). Unlike RD17, with only one developed area, RD 1614 is on the southern edge of the city Stockton and is heavily urbanized. It is bordered on the south by the San Joaquin River and on the north by Calaveras River. The confluence of the two rivers forms the western end of the district, which is at sea level. The land slopes upward to the east, to an elevation of eight feet where it reaches central Stockton. Interstate 5 crosses the rivers at a right angle where the elevation of the land is approximately three feet above sea level.

If a levee fails west of Interstate 5 (Figure 7, point A), the downslope (western) portion of the district would flood first and then water would back up towards the east. To prevent flooding from reaching the eastern side of I-5, emergency responders could block off the underpass beneath the highway, turning it into a cross-levee. While this may seem like an obvious solution for those east of the Interstate, for those already flooded it is more complicated. Maintaining an

open underpass would distribute waters to their neighbors to the east, keeping overall flood levels lower. However, to minimize overall damage, after blocking the underpass, officials could make a relief cut in the downstream levee (Figure 7, point B) to mitigate the flooding. This is a challenging situation for agencies charged with flood planning, since any action (or non-action) creates both winners and losers.

*Planning for relief cuts – jurisdictions, liability, and financing*

Given the potential for relief cuts to reduce flood damages, planning for flood management would wisely include this emergency procedure. San Joaquin County has flood contingency maps that show options for relief cuts under future flood scenarios. To avoid liability issues related to pre-planning an action that could damage a landowner's property, the maps only present options and assign no responsibility for the action, though it would be the Reclamation District that would implement the procedure. Although the State encourages the preparation of flood contingency maps in all Delta counties, not all have prepared them, and relief cuts might not be explicitly defined in future mapping efforts due to jurisdictional, liability, and financial concerns.

Many obstacles stand in the way of proactive flood planning and relief cuts in particular. Agencies resist allocating resources to plan for flood breaches because it might take away from resources dedicated to the first line of defense – strengthening the levees themselves. The levees provide a sense of security which hinders public understanding of flood risk in the Delta, resulting in little public support for mitigating flood damage (Baldwin, per. comm. 2008). Because flood insurance is not required for property owners behind a certified levee, many people do not realize they are in a flood prone or high-risk area. In addition, reclamation

districts typically only budget funds for levee maintenance, neglecting potential flood-fight costs for any given year.

Jurisdictional conflicts further complicate a quick response by the county, city, or state when cost reimbursement is uncertain (Figure 8). A reclamation district has jurisdiction over levees, but the county or state typically provides resources in a flood emergency. Failure to follow proper administrative procedures can jeopardize federal reimbursement. Additionally, technical assistance from the Army Corps of Engineers is always needed in a significant emergency, so chain-of-command delays are not uncommon. Other delays in siting a relief cut could be eliminated by planning for them on flood contingency maps. However, such a clear link between planned action and potential property damage is a liability concern for reclamation districts, cities, and counties. By contrast, actions taken under emergency conditions are often exempt from such liability considerations.

Financial resources for fighting floods (and lawsuits) are minimal. Flood protection is a constant service of the Delta levees, however, and costs for maintaining them are also high. The Department of Water Resources (DWR) proposed repairs and upgrades on the levee system in the Delta and Central Valley that would require an expenditure of between $7 billion and $12 billion (DWR 2005). Thus, financing flood management costs is an important concern. Californians passed bond measure Proposition 1-E in 2006 to provide approximately $4 billion for flood protection infrastructure projects. This one-time financing measure is not a permanent solution to costs that will only rise in the future as flood control infrastructure ages.

Ideas for sustainable financing can be drawn from a newly implemented policy in the European Union (EU). In 2000, the EU established a Water Framework Directive (WFD) to implement integrated river basin management. One of the key pillars of the WFD is full cost

recovery – the principle that users should pay for the water services that benefit them. If flood protection were considered a "water service" of the environment, the full cost recovery concept could appropriately be applied. Though the WFD does not address flood risk, the new November 2007 EU Directive (Directive 2007/60/EC) on "The Assessment and Management of Flood Risks" does consider this issue.

Costs for flood control in the Delta fall into three categories: 1) levee maintenance/upgrades, 2) flood-fighting, and 3) damage and recovery. All of these costs can run quite high. Levee maintenance can cost up to $5,000/linear foot. Flood-fighting on the Stewart tract in 1997 amounted to $150,000 per day, and damages from the 2004 Jones Tract levee failure cost the state over $100 million. Who pays for these costs varies spatially and temporally (e.g., locals pay for levee maintenance while all taxpayers contribute toward emergency funds).

The Delta and its levees support a number of water services to local, regional, and national beneficiaries. Local residents benefit from flood protection in their reclamation district, and they pay with assessment fees tied to this service. However, this cost is typically around $100/year per residential property (Neudeck, per. comm. 2008) and does not contribute enough for a reclamation district to fight floods if necessary. Local flood control agencies have found it difficult to gain enough public support to approve higher assessment fees for adequate levee maintenance (DWR 2005).

Non-locals benefit from the infrastructure running through the Delta that provides transportation routes, drinking water supplies, and other utilities. The nation's residents benefit from a strong state economy dependent on the Delta as a crossroads. State and federal taxpayers pay for these benefits indirectly should the state or national government reimburse local emergency responders in a flood disaster. However, these beneficiaries do not pay for flood

protection proactively, and addressing this disconnect could allow agencies to tap into a revenue stream for more sustainable flood infrastructure financing. Better levee maintenance and flood management planning can reduce the overall costs incurred by all in the aftermath of a flood.

New state flood management legislation passed in October 2007 leads the way toward regional cooperation and planning for flood management in the Central Valley and the Delta. Pitfalls remain, however, if county safety plans are not proactive in terms of planning for relief cuts where appropriate, or coordinated through the removal of jurisdictional barriers. Without a sustainable funding mechanism for the region, even these measures will be inadequate. Fortunately, regional coordination is currently receiving much needed attention.

In April 2008, the emergency managers of Contra Costa, Solano, Yolo, Sacramento, and San Joaquin Counties developed recommendations for more effective responses to flood threats in the Delta (Sacramento-San Joaquin Delta Flood Response Group 2008). This group set forth planning statements that would create pre-established Flood Fight Unified Commands composed of reclamation districts in close geographical proximity and sharing a common direct threat, thus improving coordination between districts and with local, State, and Federal agencies. While the emergency managers recommend that federal disaster assistance programs be modified to facilitate direct action by any public jurisdiction/agency in response to threats to levee integrity or to contain floodwaters, the regional plan does not address an ongoing source of financial resources for implementation.

**Conclusions and Recommendations**

We identify four key constraints to flood-smart planning and recommend a four-part approach for improvement.

1) *Perception of flood risk.* In general, the public believes levees will protect them from all floods. Limited public understanding results in little public support for flood planning and financing. Should an event occur requiring a relief cut, current development along the edge of levees exacerbates the flood damage because it is difficult for machinery to maneuver, and any house on either side of the cut will most likely be swept off its foundation (Neudeck, per. comm. 2008).
2) *Perverse Incentives.* For reclamation districts to increase their financial resources for maintaining levees and fighting floods, they encourage more development in the floodplain to collect more fees from property assessments. The act of encouraging residents to develop in dangerous locations seems counterintuitive to providing for flood protection and human safety.
3) *Litigation threats.* Given the potential for significant property damage, all agencies remain vulnerable to litigation after a flood. Residents might sue for damages because the county made a decision to make a relief cut near their property. This liability is a disincentive for proactive planning of relief cuts.
4) *Reimbursement uncertainty.* Historical flood accounts, flood fights, and flood damage recovery accounts demonstrate that local entities are not always reimbursed by the federal government for their expenditures. This administrative red tape discourages agencies from quickly providing disaster assistance that may avert further flood damages.

We make four recommendations to improve flood management planning in the Delta.

1) *Acknowledge that levees will fail.* History shows that Delta levees can fail. The potential impacts of a single failure or multiple failures are catastrophic (DWR 2005).

Developers, residents, legislators, and the general public must acknowledge this fact and then move forward with appropriate planning to create a better informed public that is prepared for disaster.

2) *Explicitly plan for emergency actions such as relief cuts before the flood occurs.* Planning potential options for emergency response facilitates quick action that might avert catastrophic consequences of levee failures. Locating open space (e.g., parks) proximate to potential sites well-suited for relief cuts and implementing significant housing setbacks from levees are useful planning measures.

3) *Support interagency cooperation.* Interagency cooperation for safety planning with shared financial responsibility will put safety, protection, and prevention first, removing agency hesitation and promoting a faster collaborative response. Freed from worry over liability, litigation, or financial reimbursement concerns for stepping outside of their jurisdiction, agencies could form a more cohesive, timely, and effective response in the face of flood disasters. Emergency response planners in Delta counties are already encouraging an institutional framework to address this issue (Sacramento-San Joaquin Delta Flood Response Group 2008).

4) *Apply full cost recovery concept.* Beneficiaries of the "water service" of flood protection with respect to property, human safety, infrastructure, and the market economy should share the costs. Full cost recovery would provide a more sustainable fund paid for by all beneficiaries of the Delta levee system at the local, regional, and national levels. Levee maintenance, flood planning, emergency response, and recovery would all be covered under this approach.

**Figures**

Figure 1. Delta region map

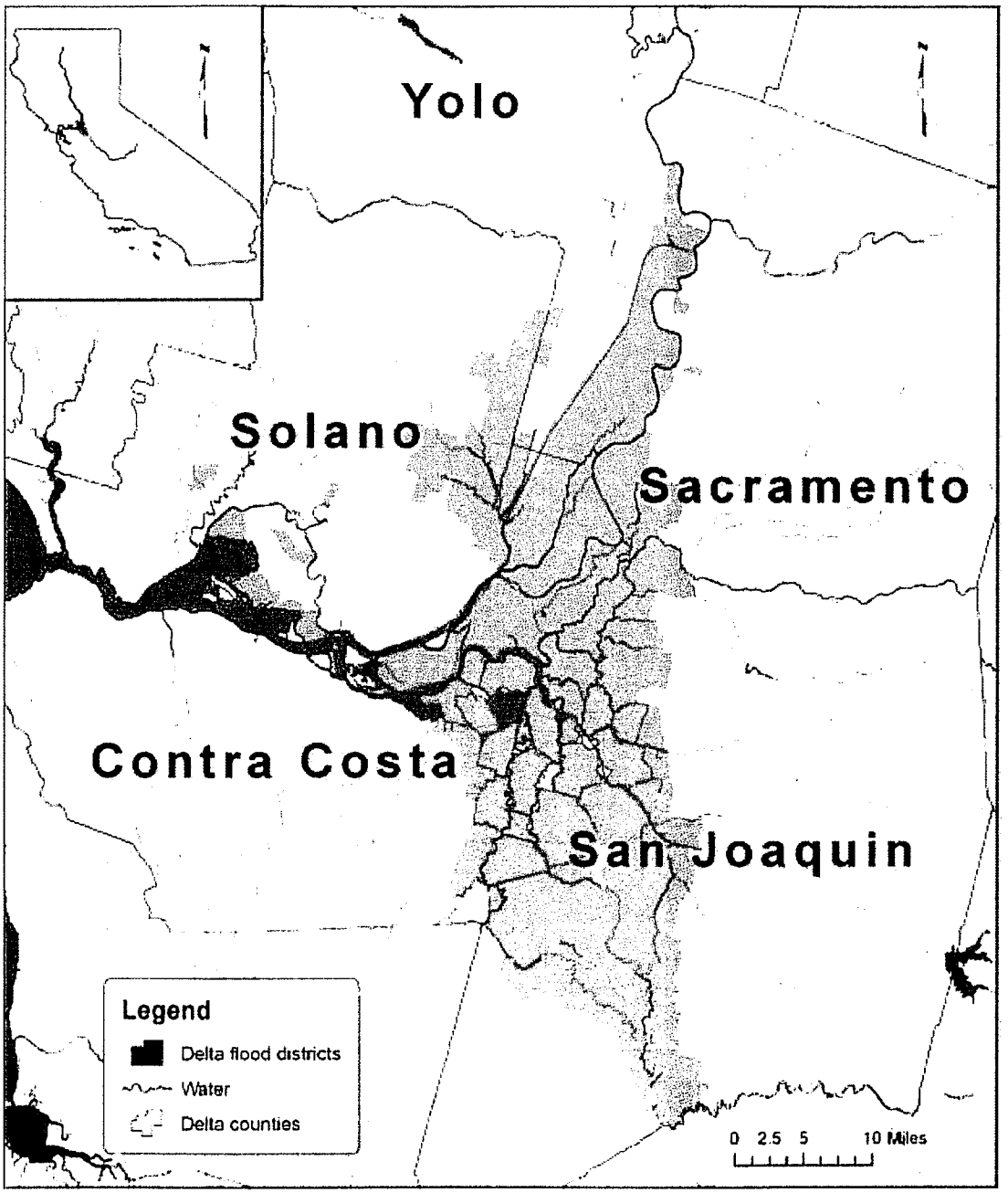


Figure 2. Relief cut schematic showing development on a tract or island between two levees in cross section and plan view. Sketch A shows the rivers under non-flood conditions. Sketch B shows a breach in the upslope levee and floodwaters filling the tract. In sketch C, a relief cut is made in the downslope levee, allowing water to drain out of the tract into the downslope river, lowering flood heights.

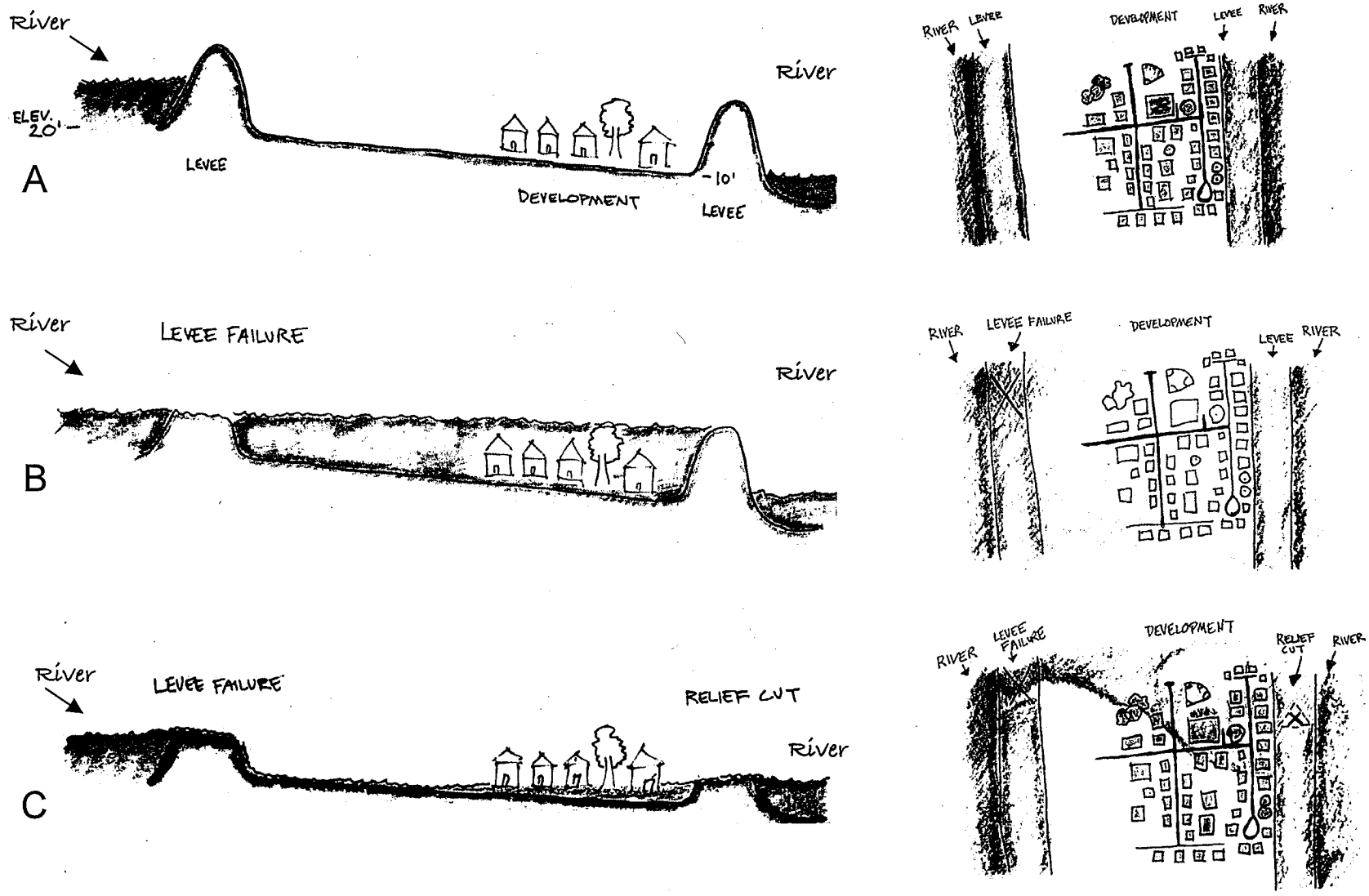


Figure 3. Photograph of scour from levee relief cut. Note that scour occurred on both sides of the levee over approximately 1000 feet.

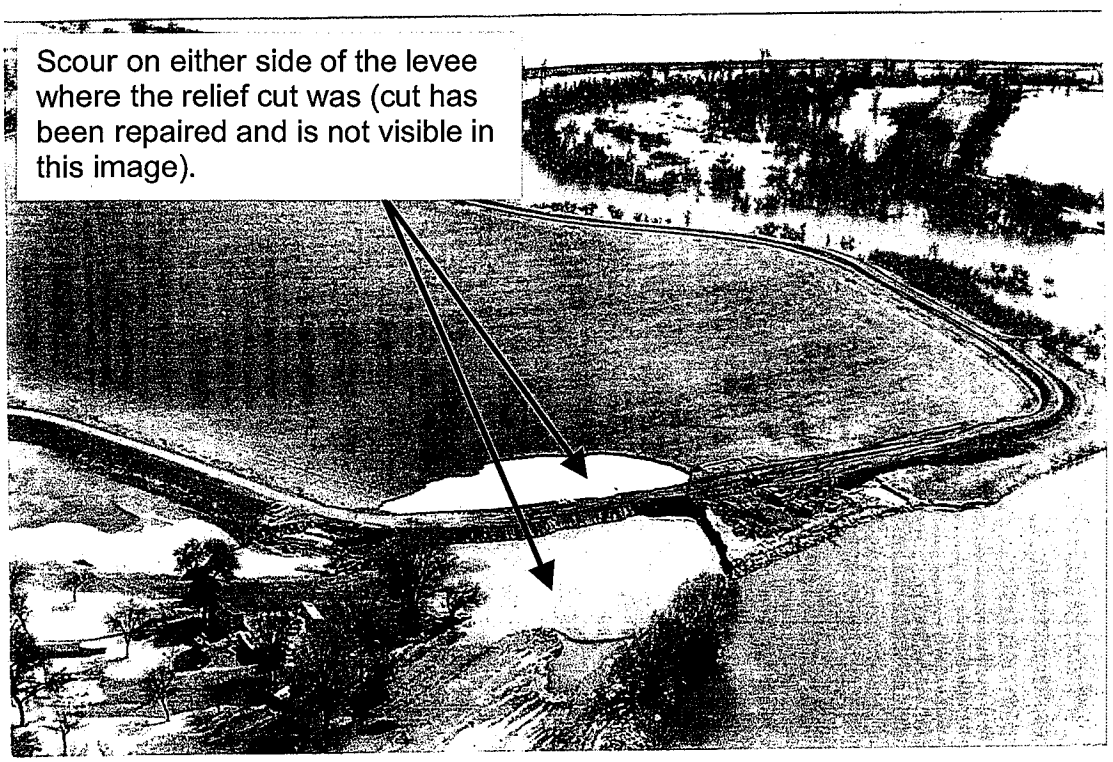


Figure 4. Flood contingency map. San Joaquin River, East Bank. This is an example of the new planning maps being developed for San Joaquin County Office of Emergency Services. The text boxes contain flood history for the area, special flood considerations, and actions to be taken in the event of a future flood. Details for specific areas will be shown in figure 5.

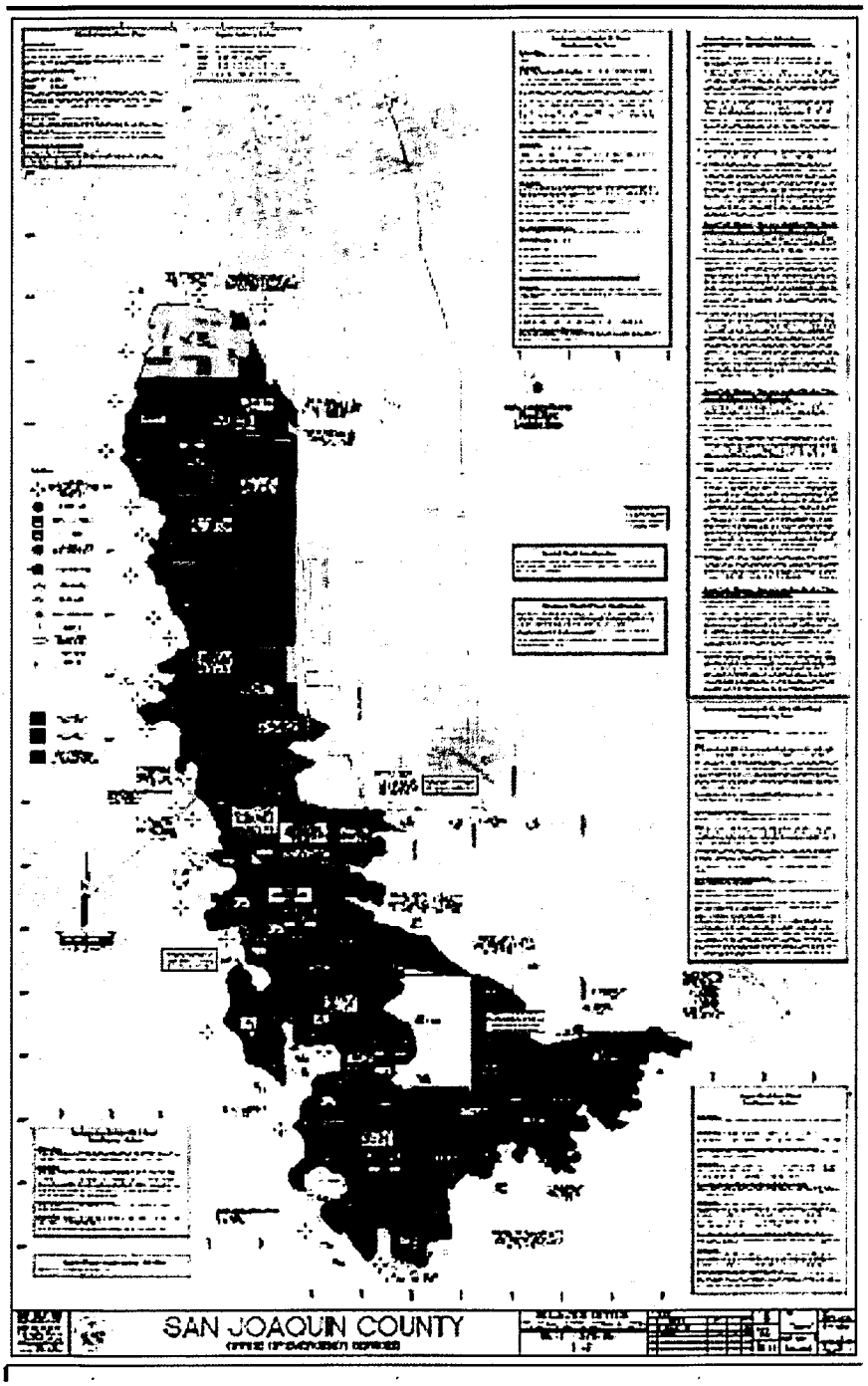


Figure 5. Weston Ranch, Reclamation District 17

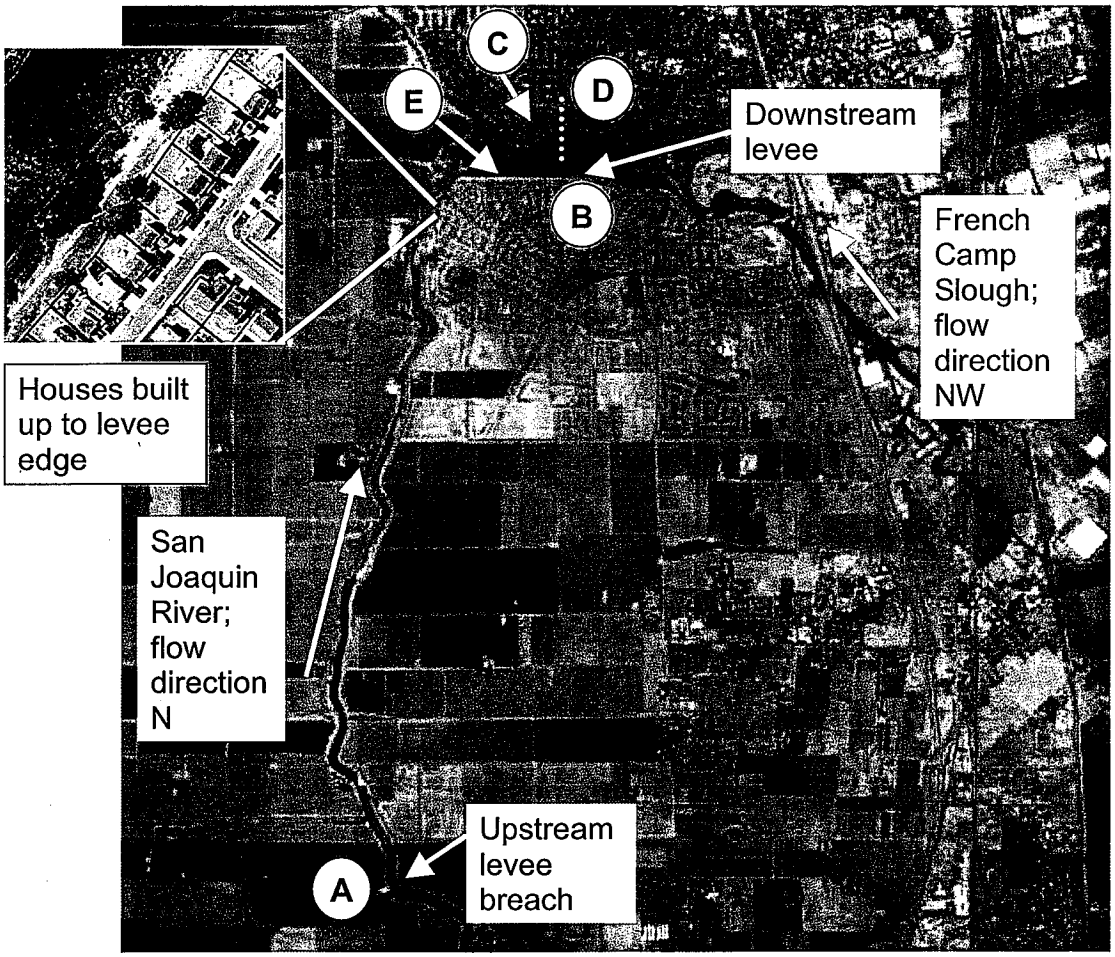
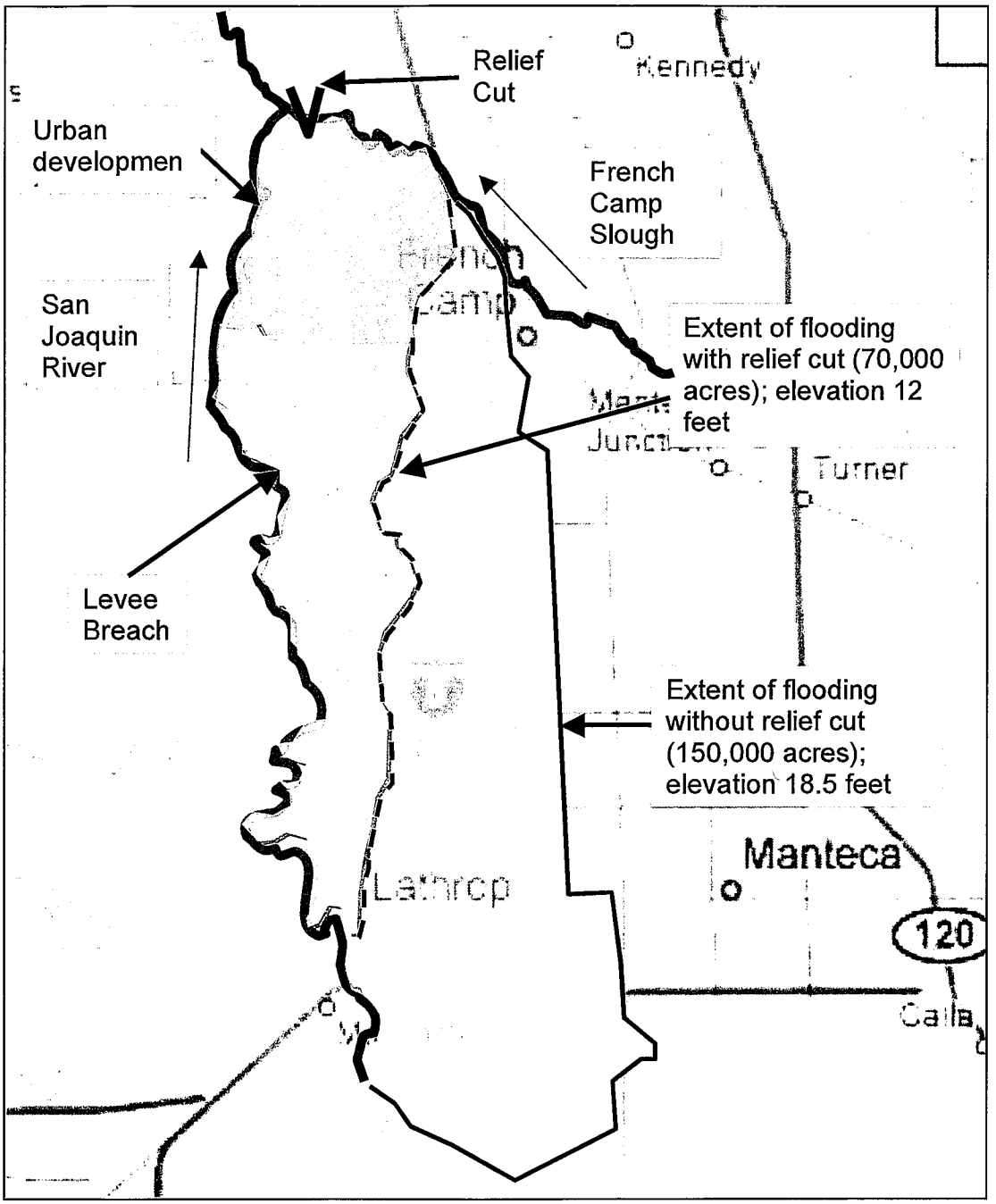


Figure 6. Reclamation District 17. Darkest blue indicates Weston Ranch development. Medium blue shows the predicted extent of flooding with a relief cut. Light blue shows the predicted extent of flooding without a relief cut.




**Legend**

Extent of flooding without relief cut

Extent of flooding with relief cut

Direction of river flow

Figure 7. South Stockton flood scenario, Reclamation District 1614

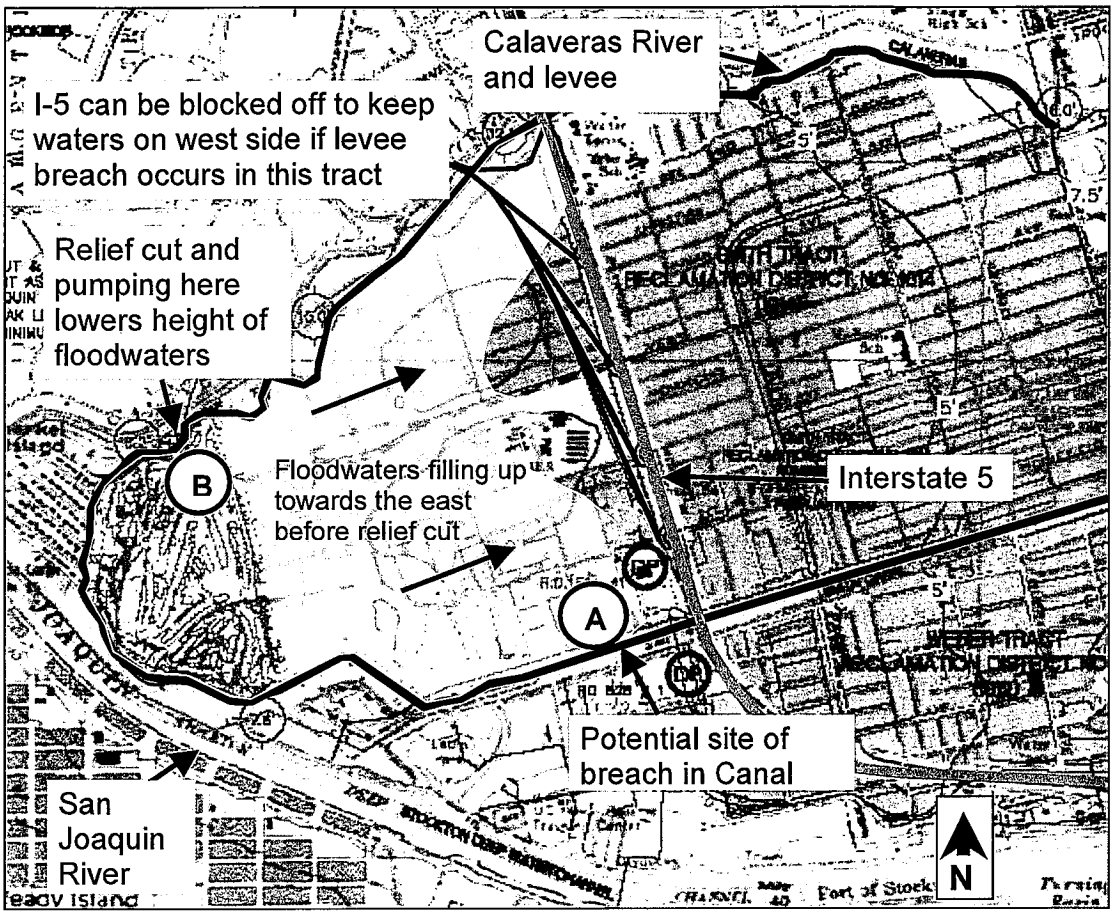
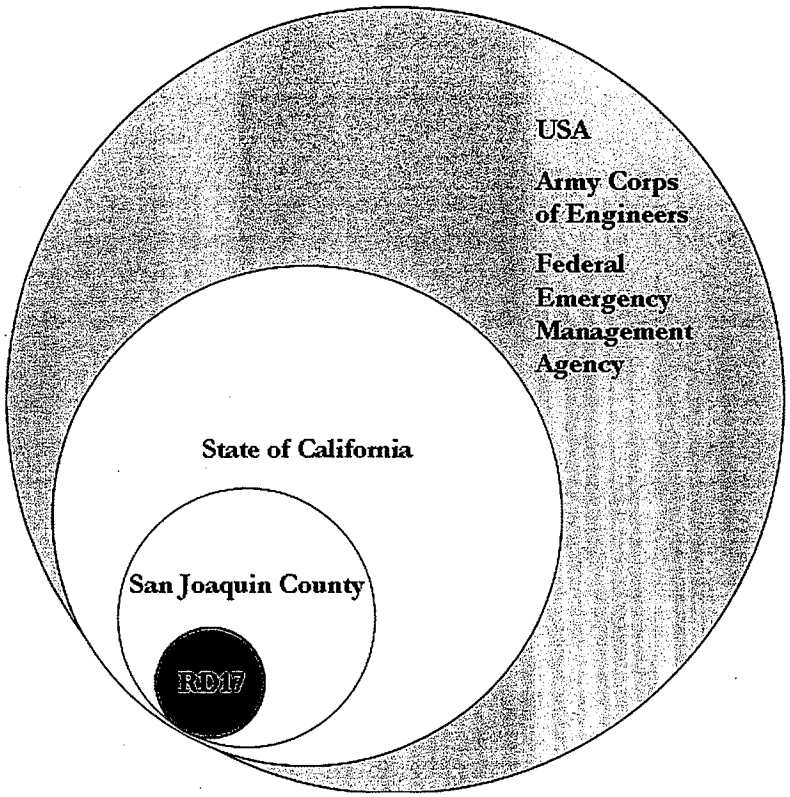


Figure 8. Jurisdictional responsibilities hierarchy for example of Reclamation District 17



**References**


Allcorn, W. 2003. *The Maginot Line 1928-45.* Oxford: Osprey Publishing.

Baldwin, Ron. Personal Communication March 20, 2008 and April 8, 2008.

California Department of Water Resources, United States Army Corps of Engineers, California Department of Fish and Game. Delta Risk Management Strategy Home Page. http://www.drms.water.ca.gov Accessed April 2008.

California Department of Water Resources (DWR). January 2005. Flood Warnings: Responding to California's flood crisis. http://www.publicaffairs.water.ca.gov/newsreleases/2005/01-10-05flood_warnings.pdf

Court of Appeal, State of California, Third Appellate District (San Joaquin). Thousand Trails, Inc., et al., Plaintiffs and Appellants, v. California Reclamation District Number 17. 2004. C042328.

Eisentstein, W., Kondolf, G.M, and John Cain. 2007. "Reenvisioning the Delta: Alternative futures for the heart of California."

[KSN, Inc.] Kjeldson, Sinnock, and Neudeck, Inc. 2006. San Joaquin County Office of Emergency Services Flood Contingency Map for Reclamation Districts 17, 2064, 2075, 2094 and 2096. Stockton.

Neudeck, Chris. Personal Communication April 4, 2008 and April 8, 2008

Sacramento-San Joaquin Delta Flood Response Group. "Basis for Regional Flood Response Planning." White Paper. April 2008.

San Joaquin County Office of Emergency Services. 2008. Flood Contingency Map.

URS Corporation/Jack R. Benjamin & Associates prepared for California Department of Water Resources (ACOE). 2006. Delta Risk Management Strategy Technical Papers available at http://www.drms.water.ca.gov/ITFP/

Water Framework Directive (WFD). 2000. Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy.