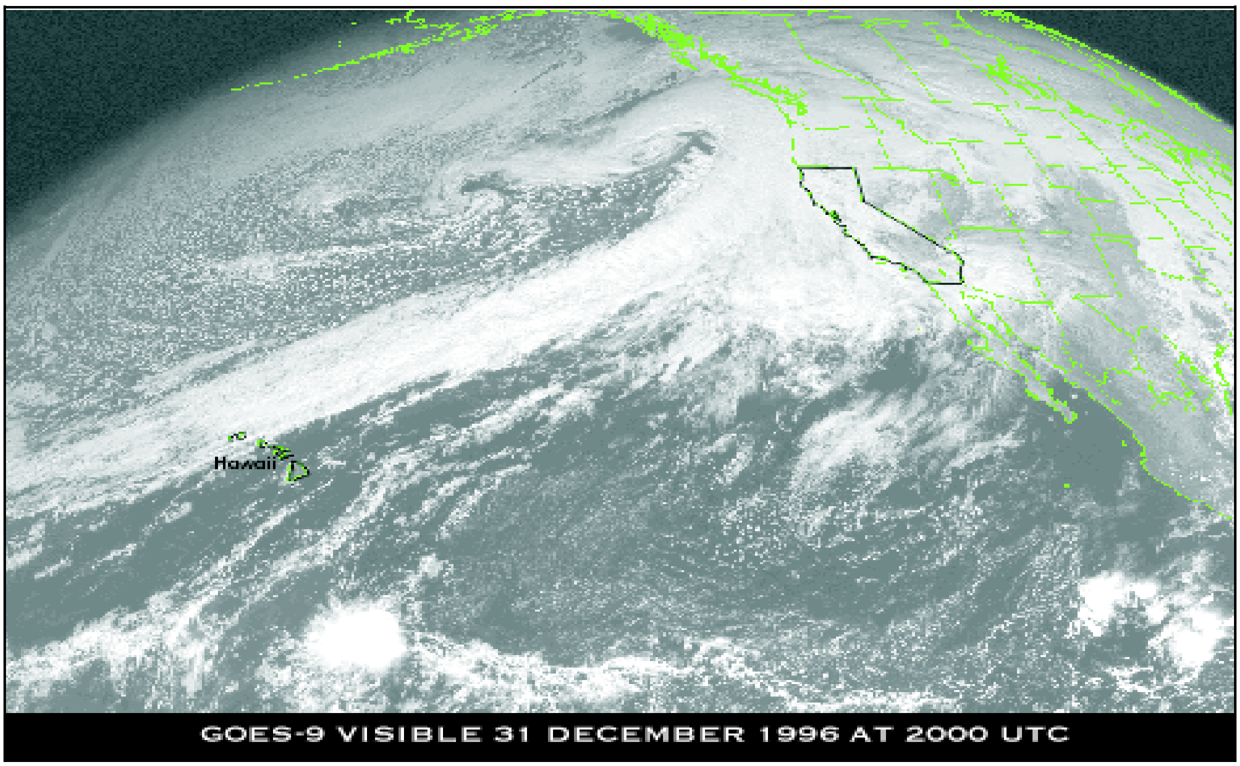
# CHAPTER 5

# SYSTEM PERFORMANCE DURING RECENT FLOODS




US Army Corps of Engineers
Sacramento District

Post-Flood Assessment for 1983, 1986, 1995, and 1997
Central Valley, California

# CHAPTER 5

# SYSTEM PERFORMANCE DURING RECENT FLOODS

## INTRODUCTION

The performance of the flood management system for the Sacramento and San Joaquin River basins during recent floods is discussed in this chapter. Four major floods are analyzed in detail–1983, 1986, 1995, and 1997. The description of each flood includes prestorm and storm conditions; system problems (including overtopping, levee breaches, seepage, and sedimentation); corrective actions to solve problems; economic damages sustained due to these problems; and economic damages prevented through the operation of the flood management system.

## FLOODED AREA MAPS

For each of the four major floods evaluated, maps were developed to delineate the areas of flooding. Each flood has an index figure and a series of figures (with 12 views, a through L) that shows the extent of flooding for each major flood. Figure 5-1 and Figures 5-2a through 5-2L for 1983; Figure 5-3 and Figures 5-4a through 5-4L for 1986; Figure 5-5 and Figures 5-6a through 5-6L for 1995; and Figure 5-7 and Figures 5-8a through 5-8L for 1997.

The production of the flooded area maps required several steps:

1. Available sources of photographic flood coverage information were researched. It was determined that the most accessible and extensive aerial photographic surveys in the Central Valley are maintained at the California Department of Water Resources (DWR) Photogrammetry Department. In addition to accessibility, DWR photographic coverage is the most comprehensive and well-organized set of aerial photographic surveys.

2. A detailed inventory was prepared of DWR photographs for the four most recent major floods in the Central Valley (1983, 1986, 1995, and 1997).

3. Each aerial survey set was reviewed to determine the number of available photographs, and whether the set was complete. Prints of any missing photographs were ordered.

4. Copies were made of flight-line maps showing the center location of each photograph and indicating the 1:24,000 scale U.S. Geological Survey (USGS) map for the area. DWR maintains a set of reduced USGS maps displaying flight lines for almost every survey.

5. The photographic sets were laid out using the flight-line maps as a guide and were visually checked for areas of inundation. Flooded areas visible on the photographs were outlined on 1:24,000 scale USGS maps. Many flight lines did not include the entire

flooded area. In these cases, the delineated flood outline included only the flood extent shown in the photographs.

6. The flooded areas drawn on the USGS maps were digitized and imported into a GIS coverage for presentation. Areas not covered by flight lines, but known to be inundated, such as leveed river reaches and bypasses, were filled by inference and added to the GIS coverage.

7. After review by Corps and DWR staff, additional areas of inundation were included and identified as inferred. The inferred areas shown on the figures are based on other flood events or FEMA GIS coverages.

8. Levee failure locations, with breaks and overtopping, were also noted in the review and added to the figures.

## ESTIMATES OF DAMAGES SUSTAINED

Previously reported damage data were used in determining the value of property damages during the 1983, 1986, 1995, and 1997 floods. The flood damage data are presented by county, not by river basin, reflecting the manner in which they were compiled. In some cases, if only part of a county is in either the Sacramento River Basin or the San Joaquin River Basin, the damage figures reflect some damage outside the river basins.

Flood damage data have been divided into as many categories as available. In some cases, however, categories have been combined by those who have compiled the data. For example, for the 1986 flood, damage estimates by county are reported as public and private damages only, but more detail is provided for other events. Public damages would include subcategories such as roads, other infrastructure, and public buildings. The subcategories that comprise each category in a table are unclear due to the lack of detail in the data sources. Sometimes, however, some general information was available and is included in the descriptions for specific events.

When reviewing damage estimates, the reader should be aware of the following limitations:

- Damage data represent flood damages resulting from all potential sources (i.e., interior drainage and overland flows) and not just levee breaks and overbank flooding.

- Much of the data from the sources are incomplete. Missing data are represented by dashes in the tables.

Table 5-1 is a summary of the estimated damages sustained for the four major floods.

## ESTIMATES OF DAMAGES PREVENTED

Estimates of damages-prevented values were developed from U.S. Army Corps of Engineers data. Each year, the Sacramento District of the Corps estimates the reduction in flooding

**TABLE 5-1**
**ESTIMATES OF DAMAGES SUSTAINED SUMMARY**
**(values in $ millions)**

| Event (Year) | Sacramento River Basin | San Joaquin River Basin | Total |
|---|---|---|---|
| 1983 | $91 | $324 | $415 |
| 1986 | $172 | $15 | $187 |
| 1995 | $305 | $193 | $498 |
| 1997 | $301 | $223 | $524 |
| Note : Values represent conditions and price levels for the year of the event. | | | |

damages attributable to projects constructed, operated, or maintained by Federal agencies. This includes projects built by the Corps and USBR and projects turned over to State or local agencies. Over the years, different methodologies and degree of detail have been used to determine the magnitude of damages prevented.

Estimated damages from preproject flows were determined based on size of area flooded, depth and duration of flooding, and value of items (structures, contents, agriculture, infrastructure) at risk of being damaged. Flood areas were related to some index point to evaluate the effectiveness of the project in reducing flood damages.

For each project under preproject conditions, an estimated flow at which potential damages begin was determined to be the nondamaging flow. Any flow that is greater than the estimated nondamaging flow would cause some dollar damage to the related area. To represent project conditions, the nondamaging flow was increased to represent channel or levee improvements or, for reservoir projects, inflows were reduced to the outflow levels to determine nondamaging points.

For each given year, maximum preproject and postproject flows were collected. Preproject damages were estimated based on flow-damage curves. Postproject flows were used to estimate residual damages and were compared with historical damages for consistency. Damages prevented represent the difference between the preproject estimates and the estimated residual damage. Table 5-2 is a summary of the estimated damages prevented for the four major floods.

The following is a list of the major projects that provide damage reduction within the Sacramento and San Joaquin valleys. These projects are discussed in detail in Chapters 2 and 3. In some cases, individual projects have been grouped together when they collectively protect the same area, while only portions of other projects were assessed. If applicable, variances from previous descriptions are denoted.

**Sacramento River Basin:**

- Shasta Dam and the Sacramento River Flood Control Project (SRFCP)—includes nearly 1,000 miles of levees, overflow weirs, and bypass channels.
- Sacramento River - Major and Minor Tributaries—damage estimates incorporate about 170 miles of channel and levee improvements to Cherokee Canal, Butte, Chico, Deer, Elder, and Mud creeks.
- Black Butte Dam

**Feather River Basin:**

- Oroville Dam and Feather River Levees
- New Bullards Bar Dam

**American River Basin:**

- Folsom Dam and the American River Levees

**San Joaquin River Basin:**

- Friant Dam and Lower San Joaquin River Levees—in conjunction provide flood damage reduction along the San Joaquin River
- Hidden Dam
- Buchanan Dam
- Merced County Streams—includes Bear, Burns, Mariposa, and Owens dams
- New Exchequer Dam
- Don Pedro Dam
- New Melones Dam

**Eastside Tributaries:**

- Farmington Dam, Littlejohn and Duck Creeks—includes a dam along Littlejohn Creek and diversion channel and channel improvements along Littlejohn and Duck creeks
- New Hogan Dam and Mormon Slough—includes a dam along the Calaveras and channel and levee improvements on Mormon Slough and the Stockton Diversion Canal
- Camanche Dam

**Tulare Lake Basin:**

- Isabella Dam
- Success Dam
- Terminus Dam
- Pine Flat Dam

Damage assessments presented in annual reports were determined from flow-damage curves. However, many of these flow-damage curves were outdated, and some predate construction of the project. The value of structures protected and the number of structures within the protected areas has increased over time. In the annual reports, attempts have been made to update these curves for price levels, but little has been done to adjust for development. Thus, the Corps has updated some of these damage assessments. Where applicable, these updated values are provided and denoted (shown as "updated") within the damages-prevented tables under each major flooding event. Otherwise, the damages-prevented values listed in the tables are from the corresponding year Corps annual report.

**TABLE 5-2**
**ESTIMATES OF DAMAGES PREVENTED SUMMARY**
**(values in $ millions)**

| Event (Year) | Sacramento River Basin | San Joaquin River Basin | Total |
|---|---|---|---|
| 1983 | $2,833 | $247 | $3,080 |
| 1986 | $9,881 | $324 | $10,205 |
| 1995 | $3,541 | $156 | $3,697 |
| 1997 | $20,417 | $811 | $21,228 |
| Note : Values represent conditions and price levels for the year of the event. | | | |

## FLOODS OF 1983

## DESCRIPTION OF STORMS

No one single storm caused the flooding in 1983. Northern and Central California experienced flooding incidents from November through March due to numerous storms. Typically, weather patterns that develop in the Aleutian Islands and Bering Straits have the greatest influence on winter weather within California. In 1983, however, California weather was influenced significantly by unusual rises in the ocean temperature and reversals in wind patterns along the equator in the South Pacific. These events are often called "El Nino" and generally occur every 2 to 10 years.

The impact of "El Nino" on California weather in 1982-83 was complex. The high-pressure ridge between 10 and 20 degrees north latitude was magnified by the heat from the warmer than normal ocean water. Simultaneously, extremely low air pressures were observed over the Gulf of Alaska. These contrasting pressure extremes caused the westerly airflow across the Pacific to double. The jet stream that directs storms into California was intensified and displaced to the south so that storms hit the Central California coast fiercely and more often. Data from several of the larger storms are shown in Table 5-3.

1983 was one of California's wettest water years in this century. The statewide precipitation averaged 190 percent of normal, with many areas well over 220 percent. New precipitation records were set at 49 locations throughout California; several records for stations in the Sacramento and San Joaquin River basins are shown in Table 5-4.

During 1983, seasonal snowpack records were set at three-fourths of the snow courses measured in the Sierra Nevada. On May 3, 1983, snow water content in the Sierra exceeded 230 percent of normal, and the ensuing runoff resulted in approximately four times the average volume for Central Valley streams. Table 5-5 summarizes the percent of normal precipitation for three runoff regions in the Sacramento and San Joaquin River basins.

## OPERATIONAL CONSTRAINTS

The stage for a disastrous year of flooding was set even before the 1983 water year began. In some parts of California, September 1982 (the close of the 1982 water year) was one of the wettest Septembers on record. Subtropical moisture from Hurricane Olivia combined with a well-above-average carryover from the very wet 1982 water year to infringe on the flood-reservation space in many reservoirs (14 of the 18 identified projects in Table 5-6 ), and soils became so saturated that the heavy runoff from the 1983 storms posed an immediate flood threat. The 1982 and 1983 water years are the wettest pair of years on record.

## TABLE 5-3
## MAJOR STORMS IN 1983 AND PRECIPITATION TOTALS FOR SELECTED LOCATIONS

| Date | Location | Precipitation (inches) | River Basin |
|---|---|---|---|
| September 24-26 | Wishon Reservoir | 8.10 | Kings River |
| October 21-26 | Blue Canyon | 8.00 | American River |
| November 29-30 | Georgetown | 8.70 | American River |
| December 13-17 | Honeydew | 22.10 | Feather River |
| December 19-22 | Strawberry | 13.00 | Feather River |
| January 22-29 | Brandy Creek | 9.50 | Sacramento River |
| February 25-March 3 | De Sabla | 14.70 | Feather River |
| March 12-13 | Bucks Ridge | 9.70 | Feather River |

## TABLE 5-4
## RECORD HIGH PRECIPITATION FOR 1983

| Station | Mean Yearly Rainfall (inches) | Previous Maximum (inches) | Year | 1983 Maximum (inches) |
|---|---|---|---|---|
| Auburn | 33.72 | 61.50 | 1982 | 63.79 |
| Folsom | 23.31 | 44.44 | 1890 | 47.64 |
| Fresno | 9.71 | 23.06 | 1969 | 23.59 |
| Knights Ferry | 17.68 | 29.52 | 1969 | 33.69 |
| Los Banos | 8.50 | 16.60 | 1978 | 18.73 |
| Rio Vista | 16.43 | 28.41 | 1958 | 31.49 |
| Shasta Dam | 61.92 | 98.07 | 1958 | 115.62 |
| Yosemite | 35.26 | 61.09 | 1938 | 66.39 |

## TABLE 5-5
## PERCENT OF NORMAL PRECIPITATION FOR NORTHERN CALIFORNIA DRAINAGE BASINS DURING WATER YEAR 1983

| Season | North[1] | Central[2] | South[3] |
|---|---|---|---|
| Fall 1982 (Sep, Oct, Nov) | 162% | 236% | 318% |
| Winter 1983 (Dec, Jan, Feb) | 150% | 144% | 183% |
| Spring 1983 (Mar, Apr, May) | 221% | 199% | 199% |

Notes:
1 Drainage basins of Upper Sacramento and Feather Rivers
2 Drainage basins from Yuba to Merced Rivers
3 Drainage basins from Upper San Joaquin to the Kern River

Although none of the major reservoirs in the Sacramento and San Joaquin River basins reached capacity during any of the 1983 flooding incidents (Table 5-6), all major reservoirs were operating in their flood management reservation pool. For example, 44 percent of the flood management reservation pool in Shasta Lake (Sacramento River) remained in early March, while only 10 percent of the flood management reservation pool for Don Pedro (Tuolumne River) remained in mid-March. All of the major reservoirs were into their flood management reservation pool by the end of March. All reservoirs either reached or nearly reached design capacity during peak runoff in June and July due to the record snowpack. Thus, dam operations during the flooding incidents were constrained by the record snowpack in the Sierra Nevada.

In addition to the high reservoir storage, the weirs in the Sacramento River Basin were active throughout much of the 1983 water year. The weirs along the Sacramento River, which act as safety valves relieving pressure on river levees by diverting excess water to the bypasses, began operating early in the water year. Floodwater entered the Butte Basin and the Sutter and Yolo Bypasses for short periods during November and December. Beginning on January 25, all fixed weirs in the system overflowed without interruption until early April; the sole exception was the Moulton Weir, which twice briefly ceased flowing.

## AREAS AFFECTED BY FLOODING

Recorded areas affected by flooding for the 1983 floods in the Sacramento and San Joaquin River basins are shown in Table 5-7. Failures in the Sacramento River Basin were limited to a private levee on the Sacramento River and one failure on Cache Creek. In the San Joaquin River Basin, levee breaks caused flooding at four locations along the San Joaquin River. In addition, four levees failed in the Delta, resulting in partial or total flooding of some Delta islands. The extent of flooded areas, as determined from aerial photography taken in January and March, for the 1983 floods are shown on Figure 5-1 and Figures 5-2a through 5-2L. Levee breaks shown on the figures are based on breaks identified in the photographs and other available data.

## DAMAGES SUSTAINED

Tables 5-8 and 5-9 show damages by county from rain floods in 1983 in the Sacramento River Basin and the San Joaquin River Basin. These data were previously reported in a 1983 Corps document entitled "Report on the 1983 Rain and Snowmelt Floods, Central Valley, California"; this is the only available data source for this event. Snowmelt flood damage data were not available for many counties, however, the damages collected for Kings and Tulare Counties are a result of Tulare Lakebed inundation that began in the January rain floods and peaked during snowmelt in July. The data in this report were derived from several sources, as identified in the footnotes to the tables. It is unclear what subcategories comprise each category due to limited information. Damage categories include private damages, public damages, county agency agricultural damages, and road (on the Federal aid system) damages. Public utilities and California Department of Food and Agriculture data were not included due to possible redundancy with public damages and county agency agricultural damages. The selected categories chosen appear to best reflect the damages.

## DAMAGES PREVENTED

Damages prevented by flood management system operations during the 1983 floods in the Sacramento and San Joaquin River Basin are shown in Tables 5-10 and 5-11. Damages prevented are given in 1983 dollars. The pre and postproject flows in the tables illustrate the reduction in peak flows resulting from operation of the flood management system for the event. No flood hydrographs were prepared for 1983 because the storm pattern produced a series of smaller rainfall-runoff events that did not heavily stress the flood control capabilities of tributary projects. Most high water was after the rain flood period during snowmelt runoff, May through June 1983.

## TABLE 5-6
## STORAGE CONDITIONS FOR PROJECTS DURING 1983 RAIN FLOODS

| Project | Storage Capacity | | As of November 1 | | Event | |
|---|---|---|---|---|---|---|
| | Total Storage (TAF[1]) | Flood Mgmt Storage (TAF[1]) | Total Storage (TAF[1]) | Available Flood Mgmt Storage | Total Storage (TAF[1]) | Flood Mgmt Storage Remain |
| **Sacramento River Basin** | | | | | | |
| Shasta Dam and Lake | 4,552 | 1,300 | 3,436 | 86% | 3,975 | 44% |
| Black Butte Dam and Lake | 144 | 136 | 23 | 89% | 65 | 58% |
| Oroville Dam and Lake | 3,538 | 750 | 2,742 | 106% | 2,901 | 85% |
| New Bullards Bar Dam and Lake | 966 | 170 | 487 | 282% | 852 | 67% |
| Folsom Dam and Lake | 977 | 400 | 728 | 62% | 742 | 59% |
| **San Joaquin River Basin** | | | | | | |
| Friant Dam and Millerton Lake | 521 | 170 | 325 | 115% | 424 | 57% |
| Hidden Dam and Hensley Lake | 90 | 65 | 29 | 94% | 38 | 80% |
| Buchanan Dam and Eastman Lake | 150 | 45 | 106 | 98% | 125 | 56% |
| New Exchequer Dam and Lake McClure | 1,025 | 400 | 652 | 93% | 820 | 51% |
| Don Pedro Dam and Lake | 2,030 | 1,340 | 1,650 | 28% | 1,894 | 10% |
| New Melones Dam and Lake | 2,420 | 450 | 1,352 | 237% | 2,085 | 74% |
| **Eastside Tributaries** | | | | | | |
| Farmington Dam and Lake | 52 | 52 | No Data | No Data | No Data | No Data |
| New Hogan Dam and Lake | 317 | 165 | 220 | 59% | 220 | 59% |
| Camanche Dam and Lake | 431 | 200 | 310 | 61% | 317 | 57% |
| **Tulare Lake Basin** | | | | | | |
| Isabella Dam and Lake | 568 | 398 | 312 | 64% | 467 | 25% |
| Success Dam and Lake | 82 | 75 | 16 | 88% | 65 | 23% |
| Terminus Dam and Lake Kaweah | 143 | 142 | 27 | 82% | 84 | 42% |
| Pine Flat Dam and Lake | 1,000 | 475 | 742 | 54% | 765 | 49% |
| Notes:<br>1 Storage values rounded to nearest 1,000 acre-feet | | | | | | |

## TABLE 5-7
## AREAS AFFECTED BY FLOODING DURING 1983 RAIN FLOODS

| Stream | Area | Description |
|---|---|---|
| **Sacramento River Basin** | | |
| Sacramento River | Glenn County | Private levees overtopped in Hamilton City (early March) |
| Cache Creek | Yolo County | South levee failed 2 miles east of Woodland, inundating 600 acres (Jan 24) |
| **San Joaquin River Basin** | | |
| San Joaquin River | RD 2064 | Levee failed near town of Vernalis; 6,000 acres flooded (March 29) |
| San Joaquin River | RD 2100 | Levee failed near the confluence of the Tuolumne River; 500 acres inundated (Mar 5) |
| Eastside Bypass | Merced County | West levee was breached opposite Owens Creek; 3,000 acres inundated (Feb 4) |
| San Joaquin River | Madera County | Levee breached 1 mile upstream from the Chowchilla Canal Bypass control structure; 3,000 acres inundated |
| Firebaugh Canal | Fresno County | East levee breached in two places |
| **Sacramento-San Joaquin Delta** | | |
| San Joaquin River | Venice Island | Eastern levee breach; 3,000-acre island inundated (Nov 30, 1982) |
| Miner Slough | Prospect Island | Levee failure (Jan 30) |
| Middle River | Mildred Island | Levee failure (Jan 27) |
| Old River | Fay Island | Levee failure (Jan 27) |
| **Tulare Lake Basin** | | |
| Kings, Kaweah, Tule, and Kern Rivers[1] | Tulare Lakebed | 82,000 acres inundated (Jul 13) |
| Notes:<br>1 Tulare Lakebed inundation began in January and peaked in July | | |

**TABLE 5-8**
**1983 RAIN FLOOD DAMAGES BY COUNTY**
**IN THE SACRAMENTO VALLEY**
**($1,000)[1]**

| County | Private Damages[2] | Public Damages[3] | County Agency Agricultural Damages[4] | Road Damages[5] | Total by County |
|---|---|---|---|---|---|
| Butte | $9,270 | $4 | $8,855 | $280 | **$18,409** |
| Colusa | $1,200 | $1,179 | ----- | $1,095 | **$3,474** |
| Glenn | $2,000 | $39 | ----- | $1,310 | **$3,349** |
| Placer | ----- | ----- | ----- | ----- | **$0** |
| Sacramento | $0 | $5,258 | $3,484 | $131 | **$8,873** |
| Shasta | $962 | $1,761 | ----- | $1,300 | **$4,023** |
| Solano | $2,585 | $1,297 | ----- | $624 | **$4,506** |
| Sutter | $200 | $460 | $9,833 | $235 | **$10,728** |
| Tehama | $2,883 | $514 | $7,762 | $455 | **$11,614** |
| Yolo | ----- | $156 | $26,044 | $42 | **$26,242** |
| Yuba | minimal | $0 | 1% of orchards | $100 | **$100** |
| **Totals** | **$19,100** | **$10,668** | **$55,978** | **$5,572** | **$91,318** |

Notes:
1 All damages are in 1983 dollars.
2 Presentation to the Senate Finance Committee by the Director, California Governor's Office of Emergency Services, March 14, 1983.
3 Federal Emergency Management Agency damage survey reports including eligible and ineligible requests.
4 Individual mail and telephone conversations from counties.
5 FHWA report entitled "California Division Emergency Relief Report, January - March 1983 Storms." Includes roadways on the Federal aid system.

Source: Corps, 1983.

## TABLE 5-9
## 1983 RAIN FLOOD DAMAGES BY COUNTY IN THE SAN JOAQUIN VALLEY
## ($1,000)[1]

| County | Private Damages[2] | Public Damages[3] | County Agency Agricultural Damages[4] | Road Damages[5] | Total by County |
|---|---|---|---|---|---|
| Fresno | $100 | $7,060 | $5,648 | $616 | **$13,424** |
| Kern | $2,750 | $356 | $7,500 | $1,328 | **$11,934** |
| Kings[6] | $420 | $1,998 | $95,000 | $550 | **$97,968** |
| Madera | $200 | $0 | $40,000 | $100 | **$40,300** |
| Merced | $200 | $414 | ----- | ----- | **$614** |
| San Joaquin | no listing | $25,204 | $97,533 | $35 | **$122,772** |
| Stanislaus | $111 | $541 | $12,200 | $35 | **$12,887** |
| Tulare[6] | $100 | $844 | $23,750 | $37 | **$24,731** |
| **Totals** | **$3,881** | **$36,417** | **$281,631** | **$2,701** | **$324,630** |

Notes:
1 All damages are in 1983 dollars.
2 Presentation to the Senate Finance Committee by the Director, California Governor's Office of Emergency Services, March 14, 1983.
3 Federal Emergency Management Agency damage survey reports including eligible and ineligible requests.
4 Individual mail and telephone conversations from counties.
5 FHWA report entitled "California Division Emergency Relief Report, January - March 1983 Storms." Includes roadways on the Federal aid system.
6 Damages in the Tulare Lakebed began in January and peaked in July, with 82,000 acres flooded.

Source: Corps, 1983.

## TABLE 5-10
## DAMAGES PREVENTED DURING 1983 RAIN FLOODS IN THE SACRAMENTO VALLEY

| Project | Preproject Flow (cfs) | Postproject Flow (cfs) | Damages Prevented ($1,000)[1] |
|---|---|---|---|
| **Sacramento River Basin** | | | |
| Shasta Dam and SRFCP | 135,700 | 60,000 | $300,000 |
| Shasta Dam and SRFCP (updated)[2] | 135,700 | 60,000 | $2,801,000 |
| Sac River Maj Min Tribs[4] | | | $1,200 |
| Black Butte Dam | 54,400 | 15,000 | $9,100 |
| Black Butte Dam (updated)[2] | 54,400 | 15,000 | $29,870 |
| **Feather River Basin** | | | |
| Oroville Dam | Nondamaging[3] | Nondamaging[3] | $0 |
| New Bullards Bar Dam | Nondamaging[3] | Nondamaging[3] | $0 |
| **American River Basin** | | | |
| Folsom Dam and American River Levees | 63,000 | 33,000 | $0 |
| Folsom Dam and American River Levees (updated)[2] | 63,000 | 33,000 | $900 |
| **TOTAL 1983 Sacramento Valley** | | | **$2,832,970** |

Notes:
1 Damages prevented are in 1983 dollars
2 Damages prevented updated based on new flow/damage relationships
3 Actual flow was never reported but was less than the lowest damaging flow

## TABLE 5-11
## DAMAGES PREVENTED DURING 1983 RAIN FLOODS IN THE SAN JOAQUIN VALLEY

| Project | Preproject Flow (cfs) | Postproject Flow (cfs) | Damages Prevented ($1,000)[1] |
|---|---|---|---|
| **San Joaquin River Basin** | | | |
| Lower San Joaquin River Levees[5] | | | $6,600 |
| Friant Dam | 19,400 | Nondamaging[3] | $23,690 |
| Hidden Dam | 11,700 | 4,000 | $2,900 |
| Buchanan Dam | 13,800 | 5,000 | $3,400 |
| Merced County Streams[5] | | | $10,200 |
| New Exchequer Dam | 17,600 | 8,000 | $14,400 |
| Don Pedro Dam | 35,000 | Nondamaging[3] | $12,700 |
| New Melones Dam | 25,990 | Nondamaging[3] | $12,700 |
| **Eastside Tributaries** | | | |
| Farmington Dam, Littlejohn and Duck Creeks | 16,500 | 2,000 | $6,700 |
| New Hogan Dam | 17,600 | 8,000 | $7,000 |
| New Hogan Dam (updated data)[2] | 17,600 | 8,000 | $5,100 |
| Mormon Slough | n/a | | $300 |
| Mormon Slough (updated data)[2] | n/a | | $0 |
| Camanche Dam | 7,600 | 4,000 | $400 |
| **Tulare Lake Basin** | | | |
| Isabella Dam[4] | 9,100 | Nondamaging[3] | $30,400 |
| Success Dam[4] | 12,000 | Nondamaging[3] | $11,300 |
| Terminus Dam[4] | 17,000 | Nondamaging[3] | $26,700 |
| Pine Flat Dam[4] | 50,000 | Nondamaging[3] | $79,800 |
| **TOTAL 1983 San Joaquin Valley** | | | **$135,380** |

Notes:
1 Damages prevented are in 1983 dollars
2 Damages prevented updated based on new flow/damage relationships
3 Actual flow was never reported but was less than the lowest damaging flow
4 Damages prevented for these reservoirs include values from the Tulare Lakebed and are not just determined by individual river flows
5 Multiple index points; individual flows not shown

## FLOOD OF 1986

### DESCRIPTION OF STORMS

A series of four storms between February 11 and February 19 led to the floods of 1986. A strong high-pressure ridge had developed off the west coast by February 4-5. The ridge continued to build and sharpen, and by February 11 the top portion became cut off in the eastern Gulf of Alaska and created a high-pressure cell called a "blocking high.” The "blocking high" forced the strong westerly flow across the Pacific into two branches. One branch of westerly flow (warm and moist) cut through California.

Rains from the first storm started the evening of February 11 and peaked the next day. This storm originated in the Pacific just north of Hawaii and brought up to 6 inches of precipitation to the upper Feather River Basin. On February 13, a second storm developed northeast of Hawaii. A strong cold front generated by this storm moved across northern California on February 14. Gusty winds and heavy rains hit the entire state. Behind the front, a pattern of overrunning (warm moist air flowing over cold air) produced additional rainfall through much of the following day.

On February 15, a strong, deep flow of warm moist air from Hawaii advanced south of California. On February 16, weather satellites showed enormous development along the jet stream between Hawaii and California. Southwest winds of 210 mph were reported in the jet stream. The storm, which entered south of California, began moving slowly north as a warm front. North of the warm front, strong overrunning by a deep moist southwest flow began producing heavy rainfall from the north bay counties to the Sierra Nevada. In many areas, this heavy rainfall continued with only brief breaks through February 17. Rainfall of one-half to three-fourths inch per hour was common.

Another Pacific weather system approached northern and central California on February 18. The storm originated well north of Hawaii, and thus was a much colder front in comparison to the previous storms. The snow level dropped to 5,000 feet for this storm; during the previous storms, the level was about 7,000 feet.

The heaviest precipitation from these four storms was in a band 200 miles north to 100 miles south of a line from San Francisco to Sacramento to Lake Tahoe. Over much of the area, the precipitation ranged from 100 to 200 percent of normal February precipitation for the 9-day period from February 11 through 19. The heaviest 24-hour rainfall ever recorded in the Sierra Nevada drainage was 17.60 inches on February 16-17 at Four Trees in the Feather River Basin. This was part of the 55.60 inches for the month at Four Trees, the greatest February total recorded for any station in the State. Other record precipitation totals are shown in Table 5-12. In many rivers and streams, these storms produced either record or near-record flows, as summarized on Table 5-13. A record flow of 640,000 cfs was estimated at the latitude of Sacramento. At 16 stream gages, the peak flow recorded either equaled or exceeded the previous maximum.

**TABLE 5-12**
**RECORD PRECIPITATION TOTALS, FEBRUARY 11-20, 1986**

| Location | Precipitation (inches) | River Basin |
|---|---|---|
| Citrus Heights | 12.18 | American River |
| Bucks Lake | 49.44 | Feather River |
| Clipper Mill | 39.44 | Feather River |
| Nevada City | 19.13 | Yuba River |
| Georgetown | 28.93 | American River |
| Calaveras Big Trees | 33.15 | Calaveras River |
| New Hogan Dam | 8.37 | Calaveras River |
| Westfall R S | 31.30 | San Joaquin River |
| Tiger Creek P H | 22.77 | Mokelumne River |

**TABLE 5-13**
**PEAK FLOWS FOR STREAM GAGES THAT EQUALED OR EXCEEDED PREVIOUS MAXIMUMS DURING FEBRUARY 1986**

| Stream Gage | Drainage Area (sq mi) | Previous Date | Maximum Flow (cfs) | February 1986 Maximum Flow (cfs) |
|---|---|---|---|---|
| Big Chico Creek near Chico | 72 | 1965 | 9,580 | 10,600 |
| Stony Creek below Black Butte | 738 | 1964 | 19,400 | 23,300 |
| Butte Creek near Chico | 147 | 1964 | 21,200 | 22,000 |
| Sacramento River at Wilkins Slough | 12,926 | 1983 | 32,300 | 32,700 |
| Bear River near Wheatland | 292 | 1955 | 33,000 | 48,000 |
| Sacramento River at Verona | 21,251 | 1980 | 80,900 | 92,900 |
| Sacramento River at Freeport | | 1950 | 104,000 | 117,000 |
| Feather River near Gridley | 3,676 | 1980 | 90,100 | 150,000 |
| American River at Fair Oaks | 1,888 | 1964 | 115,000 | 134,000 |
| Cosumnes River at Michigan Bar | 536 | 1950 | 42,000 | 45,100 |
| Note: February 1986 maximum flows are from USGS | | | | |

## OPERATIONAL CONSTRAINTS

Rainfall in December 1985 and early January 1986 was below normal for most of the Sacramento and San Joaquin River basins. However, storms in late January brought conditions back to normal. Rainfall began on January 29 and continued over much of the area until February 3-5. The rain stopped until February 11, when the flood-inducing rainfall began.

At the beginning of the 1986 water year, water levels in all the major reservoirs in the Sacramento and San Joaquin River basins were well below required flood management levels, providing available storage in excess of maximum flood management reservation. On November 1, 1985, three major flood management projects in the Sacramento River Basin, Shasta, Oroville and Folsom, were well above required flood management reservation levels (190 percent, 198 percent, and 114 percent, respectively). All of the reservoirs in the San Joaquin River basin also had available storage well above flood management storage reservations. Available flood management reservation storage in the San Joaquin River Basin reservoirs ranged from 123 percent for Hensley Lake to 311 percent for Eastman Lake. Due to the dry conditions in most of December and January, available storage in all major reservoirs except Folsom was above the required flood management capacity at the onset of the February storms. Folsom was slightly below the required flood management storage capacity.

During the February 1986 floods, all of the main projects for the Sacramento River operated in their flood management reservation pool and two projects exceeded their design capacity. The design capacity of Folsom Lake was exceeded when the Auburn Dam project cofferdam overtopped and failed as designed. The additional water placed Folsom Lake 1.56 feet into surcharge storage, holding 18,200 acre-feet more than the designed capacity. Due to the cofferdam failure, total releases from Folsom reached 130,000 cfs, which exceeded the previous record (1964) release by 15,000 cfs. Inflow into Lake Oroville reached a high of 266,540 cfs on February 17. Record flood management releases of 150,000 cfs made room for this unexpected volume of water. During this time, Black Butte Lake reached 168,000 acre-feet, exceeding its design capacity of 144,000 acre-feet.

The bypasses for the Sacramento River Basin provided much needed storage and flow capacity during the peak of the 1986 floods. Before the mid-February storm systems, overflow at each of the weirs had been minor or nonexistent. By February 17, however, all weirs were flowing and all except the Moulton Weir continued flowing until the last week of March. The peak flow exceeded the project design flow at the Colusa Weir, Fremont Weir, and Sacramento Weir.

Much of the San Joaquin River Basin was spared the full impact of the 1986 storms. The major projects for the San Joaquin River Basin did not encroach on their flood management reservations as did their counterparts in the Sacramento River Basin. The exception in the San Joaquin River Basin was Millerton Lake, only 16 percent of the flood management reservation remained at the end of the February event. As shown in Table 5-14, the other major reservoirs (New Melones, Don Pedro, and McClure) remained near maximum flood management reservation levels, with more than 90 percent of capacity remaining at each of these reservoirs.

The San Joaquin River did reach flood stage during mid-March 1986; the peak at Vernalis on March 19, was 29.86, 0.86 feet over the flood stage of 29 feet.

## AREAS AFFECTED BY FLOODING

Table 5-15 lists the levee breaks and areas that flooded during the 1986 floods in the Sacramento and San Joaquin River basins. As indicated, most of the system breaks were in the Sacramento River Basin. The only levee breaks in the San Joaquin River Basin were along the Mokelumne River, which is an eastside tributary and is in the northern portion of the basin south of the American River Basin. The extent of flooding is shown on Figure 5-3 and Figures 5-4a through 5-4L. The information on flood extent and levee breaks was compiled from aerial photography taken in mid to late February and mid-March, along with information from other sources.

## DAMAGES SUSTAINED

Tables 5-16 and 5-18 show private and public damages by county from flooding in 1986 in the Sacramento and San Joaquin River basins, respectively. Private damages include damage to residences and outbuildings, personal property, and businesses. Public damages include damage to public buildings and infrastructure. The private and public data were compiled by the State Office of Emergency Services (OES) and has previously been published in “Rivers of Fear: The Great California Flood of 1986,” which was the most comprehensive source of data available for this flood.

Table 5-17 shows data by county on the number of residences and businesses damaged and destroyed, the number of people injured, and the number of lives lost as a result of the 1986 flood in the Sacramento River Basin. Damage reporting in the San Joaquin River Basin, shown in Table 5-19, only tabulated the number of residences and businesses damaged as a result of flooding in 1986. The data in these two tables were compiled by the OES and found in “Rivers of Fear, The Great California Flood of 1986.”

## DAMAGES PREVENTED

Damages prevented by flood management system operations during the 1986 floods in the Sacramento and San Joaquin River basins are shown in Tables 5-20 and 5-21, respectively. Damages prevented are in 1986 dollars. The pre and postproject flows in the tables illustrate the reduction in peak flows resulting from operation of the flood management system for the event. Appendix C includes hydrographs for each event that indicate the impact of the flood management system on the flood hydrograph at selected points in the basins.

## TABLE 5-14
## STORAGE CONDITIONS FOR PROJECTS DURING 1986 RAIN FLOODS

| Project | Storage Capacity | | As of November 1 | | Event | |
|---|---|---|---|---|---|---|
| | Total Storage (TAF[1]) | Flood Mgmt Storage (TAF[1]) | Total Storage (TAF[1]) | Flood Mgmt Storage Avail. | Total Storage (TAF[1]) | Flood Mgmt Storage Remain |
| **Sacramento River Basin** | | | | | | |
| Shasta Dam and Lake | 4,552 | 1,300 | 2,085 | 190% | 4,251 | 23% |
| Black Butte Dam and Lake | 144 | 136 | 37 | 79% | 168 | -18% |
| Oroville Dam and Lake | 3,538 | 750 | 2,053 | 198% | 3,268 | 36% |
| New Bullards Bar Dam and Lake | 966 | 170 | 509 | 269% | 963 | 2% |
| Folsom Dam and Lake | 1,010 | 400 | 522 | 122% | 1,028 | -5% |
| **San Joaquin River Basin** | | | | | | |
| Friant Dam and Millerton Lake | 521 | 170 | 185 | 198% | 494 | 16% |
| Hidden Dam and Hensley Lake | 90 | 65 | 10 | 123% | 56 | 52% |
| Buchanan Dam and Eastman Lake | 150 | 45 | 10 | 311% | 85 | 144% |
| New Exchequer Dam and Lake McClure | 1,025 | 400 | 238 | 197% | 637 | 97% |
| Don Pedro Dam and Lake | 2,030 | 340 | 1,201 | 244% | 1,720 | 91% |
| New Melones Dam and Lake | 2,420 | 450 | 1,516 | 201% | 1,995 | 94% |
| **Eastside Tributaries** | | | | | | |
| Farmington Dam and Lake | 52 | 52 | No Data | No Data | No Data | No Data |
| New Hogan Dam and Lake | 317 | 165 | 95 | 135% | 253 | 39% |
| Camanche Dam and Lake | 430 | 200 | 257 | 87% | 439 | -5% |
| **Tulare Lake Basin** | | | | | | |
| Isabella Dam and Lake | 568 | 398 | 191 | 95% | 315 | 64% |
| Success Dam and Lake | 82 | 75 | 12 | 93% | 49 | 44% |
| Terminus Dam and Lake Kaweah | 143 | 142 | 14 | 91% | 86 | 40% |
| Pine Flat Dam and Lake | 1,000 | 475 | 265 | 155% | 805 | 41% |

Notes:
1 Storage values rounded to nearest 1,000 acre-feet

## TABLE 5-15
## AREAS AFFECTED BY FLOODING DURING 1986 RAIN FLOODS

| Stream | Area | Description |
|---|---|---|
| **Sacramento Valley** | | |
| Yuba River | Linda | Left bank levee failed, flooding towns of Linda, Olivehurst, and Alicia |
| Natomas-Eastside Canal | Sutter County | Levee failed near Pleasant Grove |
| Arcade Creek | Sacramento County | Levee overtopped; 500 homes inundated |
| Yankee Slough | Sutter County | Levee failed near East Nicholaus |
| American River | Auburn Dam Project | Cofferdam failed (as designed) |
| **San Joaquin Valley** | | |
| Firebaugh Canal | Fresno County | East levee breached in two places |
| **Sacramento-San Joaquin Delta** | | |
| Mokelumne River | Tyler Island | Levee failed in two places; 8,500 acres inundated |
| Mokelumne River | McCormack-Williamson Tract | Levee failed |
| Mokelumne River | Dead Horse Island | Levee failed |
| Mokelumne River | City of Thornton | Levee breached; city inundated |
| Note: McCormick-Williamson Tract and Dead Horse Island have restrictions on levee heights and are designed to be inundated if Mokelumne River gets too high. | | |

## TABLE 5-16
## 1986 RAIN FLOOD DAMAGES BY COUNTY
## IN THE SACRAMENTO VALLEY[1]
## ($1,000)[2]

| County | Private Damages | Public Damages | Total by County |
|---|---|---|---|
| Butte | $12,650 | $1,969 | **$14,619** |
| Colusa | $2,468 | $2,165 | **$4,633** |
| Glenn | $7,800 | $1,175 | **$8,975** |
| Placer | $7,950 | $8,419 | **$16,369** |
| Sacramento | $36,525 | $12,111 | **$48,636** |
| Shasta | $500 | $810 | **$1,310** |
| Solano | $11,804 | $15,431 | **$27,235** |
| Sutter | $16,735 | $3,212 | **$19,947** |
| Tehama | $6,319 | $408 | **$6,727** |
| Yolo | ----- | $250 | **$250** |
| Yuba[3] | $12,500 | $11,000 | **$23,500** |
| **Totals** | **$115,251** | **$56,950** | **$172,201** |

Notes:
1 California Governor's Office of Emergency Services.
2 All damages are in 1986 dollars.
3 Preliminary estimates from OES. Later estimates from the Corps indicated total damages of approximately $100 million.

Source: Teets and Young, 1986.

## TABLE 5-17
## RESIDENCES AND BUSINESSES DAMAGED AND DESTROYED, PEOPLE INJURED, AND LIVES LOST IN THE SACRAMENTO VALLEY RESULTING FROM 1986 RAIN FLOODS[1]

| County | Residences Damaged | Residences Destroyed | Businesses Damaged | Businesses Destroyed | People Injured | Lives Lost |
|---|---|---|---|---|---|---|
| Butte | 107 | 20 | 15 | 4 | 10 | ----- |
| Colusa | 24 | ----- | 4 | ----- | ----- | ----- |
| Glenn | 50 | 2 | 27 | ----- | 2 | ----- |
| Placer | 420 | 11 | 73 | ----- | ----- | 1 |
| Sacramento | 1,730 | ----- | 73 | ----- | ----- | ----- |
| Shasta | 300 | ----- | 100 | ----- | ----- | ----- |
| Solano | 307 | ----- | 13 | ----- | 6 | ----- |
| Sutter | ----- | ----- | ----- | ----- | ----- | ----- |
| Tehama | 100 | ----- | ----- | ----- | 1 | ----- |
| Yolo | 34 | ----- | 5 | ----- | ----- | ----- |
| Yuba | 3,000 | 895 | 150 | 150 | 30 | ----- |
| **Totals** | **6,072** | **928** | **460** | **154** | **49** | **1** |

Notes:
1 California Governor's Office of Emergency Services.

Source: Teets and Young, 1986.

**TABLE 5-18**
**1986 RAIN FLOOD DAMAGES BY COUNTY IN THE SAN JOAQUIN VALLEY[1]**
**($1,000)[2]**

| County | Private | Public | Total by County |
|---|---|---|---|
| Fresno | $840 | $450 | **$1,290** |
| Kern | ----- | ----- | **-----** |
| Kings | ----- | ----- | **-----** |
| Madera | $210 | $38 | **$248** |
| Merced | $70 | ----- | **$70** |
| San Joaquin | $6,500 | $7,238 | **$13,738** |
| Stanislaus | ----- | ----- | **-----** |
| Tulare | $20 | ----- | **$20** |
| **Totals** | **$7,640** | **$7,726** | **$15,366** |

Notes:
1 California Governor’s Office of Emergency Services.
2 All damages are in 1986 dollars.

Source: Teets and Young, 1986.

**TABLE 5-19**
**RESIDENCES AND BUSINESSES DAMAGED AND DESTROYED, PEOPLE INJURED, AND LIVES LOST IN THE SAN JOAQUIN VALLEY RESULTING FROM 1986 RAIN FLOODS[1]**

| County | Residences Damaged | Residences Destroyed | Businesses Damaged | Businesses Destroyed | People Injured | Lives Lost |
|---|---|---|---|---|---|---|
| Fresno | 31 | ----- | 11 | ----- | ----- | ----- |
| Kern | ----- | ----- | ----- | ----- | ----- | ----- |
| Kings | ----- | ----- | ----- | ----- | ----- | ----- |
| Madera | 10 | ----- | 9 | ----- | ----- | ----- |
| Merced | ----- | ----- | ----- | ----- | ----- | ----- |
| San Joaquin | 150 | ----- | 5 | ----- | ----- | ----- |
| Stanislaus | ----- | ----- | ----- | ----- | ----- | ----- |
| Tulare | 3 | ----- | ----- | ----- | ----- | ----- |
| **Totals** | **194** | **-----** | **25** | ----- | ----- | ----- |

Notes:
1 California Governor's Office of Emergency Services.

Source: Teets and Young, 1986.

## TABLE 5-20
## DAMAGES PREVENTED DURING 1986 RAIN FLOOD IN SACRAMENTO VALLEY

| Project | Pre-Project Flow (cfs) | Post-Project Flow (cfs) | Damages Prevented ($1,000)[1] |
|---|---|---|---|
| **Sacramento River Basin** | | | |
| Shasta Dam and SRFCP | 160,000 | 70,000 | $7,300,000 |
| Shasta Dam and SRFCP (updated)[2] | 160,000 | 70,000 | $3,108,000 |
| Sac River Maj Min Tribs[3] | | | $3,000 |
| Black Butte Dam | 47,000 | 25,000 | $5,500 |
| Black Butte Dam (updated)[2] | 47,000 | 25,000 | $15,860 |
| **Feather River Basin** | | | |
| Oroville Dam | 275,000 | 150,000 | $262,800 |
| New Bullards Bar Dam | 98,000 | 50,000 | $3,600 |
| **American River Basin** | | | |
| Folsom Dam and American River Levees | 209,000 | 130,000 | $4,700,000 |
| Folsom Dam and American River Levees (updated)[2] | 209,000 | 130,000 | $6,488,100 |
| **TOTAL 1986 Sacramento Valley** | | | **$9,881,360** |

Notes:
1 Damages prevented are in 1986 dollars
2 Damages prevented updated based on new flow/damage relationships
3 Multiple index points; individual flows not shown

**TABLE 5-21**
**DAMAGES PREVENTED DURING 1986 RAIN FLOOD**
**IN SAN JOAQUIN VALLEY**

| Project | Pre-Project Flow (cfs) | Post-Project Flow (cfs) | Damages Prevented ($1,000)[1] |
|---|---|---|---|
| **San Joaquin River Basin** | | | |
| Lower San Joaquin River Levees[5] | | | $17,300 |
| Friant Dam | 40,000 | 17,500 | $33,190 |
| Hidden Dam | 9,800 | 3,100 | $1,900 |
| Buchanan Dam | 15,000 | Nondamaging[3] | $6,000 |
| Merced County Streams[5] | | | $8,000 |
| New Exchequer Dam | 50,000 | 1,900 | $23,300 |
| Don Pedro Dam | 90,000 | 4,700 | $25,600 |
| New Melones Dam | 75,000 | 7,000 | $102,500 |
| **Eastside Tributaries** | | | |
| Farmington Dam, Littlejohn and Duck | 24,000 | 2,400 | $17,200 |
| New Hogan Dam | 35,000 | 7,000 | $14,000 |
| New Hogan Dam (updated data)[2] | 35,000 | 7,000 | $21,800 |
| Mormon Slough | 15,000 | Nondamaging[3] | $3,400 |
| Mormon Slough (updated data)[2] | 15,000 | Nondamaging[3] | $5,900 |
| Camanche Dam | n/a | n/a | $16,000 |
| **Tulare Lake Basin** | | | |
| Isabella Dam[4] | 14,000 | 600 | $6,000 |
| Success Dam[4] | 7,000 | 1,100 | $2,000 |
| Terminus Dam[4] | 20,000 | 3,300 | $8,000 |
| Pine Flat Dam[4] | 35,000 | 100 | $29,000 |
| **TOTAL 1986 San Joaquin Valley** | | | **$337,080** |

Notes:
1 Damages prevented are in 1986 dollars
2 Damages prevented updated based on new flow/damage relationships
3 Actual flow was never reported but was less than the lowest damaging flow
4 Damages prevented for these reservoirs include values from the Tulare Lakebed and are not just determined by individual river flows
5 Multiple index points; individual flows not shown

## FLOODS OF 1995

## DESCRIPTION OF STORM

A much stronger than normal Pacific jet stream was displaced well south of its normal position during much of the winter and early spring of 1995 due to "El Nino" conditions in the Pacific. This forced major moisture-laden storm systems directly into California. In fact, the jet stream and average storm track were displaced 15 to 20 degrees latitude south of their normal locations during January.

During January and March, the State was struck repeatedly by very strong storm systems laden with Pacific moisture. The largest storm systems hit California January 8-10 and March 5-10. Several precipitation totals for selected stations during these events are shown in Table 5-22. The major brunt of the January storms was felt by the Sacramento River Basin, whereas the San Joaquin River Basin was not as severely affected. The March storms were focused on the coastal ranges and southern California.

The flooding in early January 1995 was attributed to a series of two storms originating 500 miles north of Hawaii. The first storm front arrived on January 6. This 2-day storm produced moderate precipitation totals in northern California, 0.42 inches in Sacramento, and 3.23 inches at Blue Canyon. The second storm front arrived on January 8 and remained over northern California through January 10. During the first two days of the event, Blue Canyon received 2.15 inches, and Sacramento received 1.10 inches.

The evening of January 9-10 brought record rainfall to the already saturated floor of the Central Valley. Sacramento set a new rainfall record, receiving 4.45 inches within a 24-hour period. Other areas bordering Sacramento received even larger quantities of rainfall–Roseville recorded 7.25 inches of precipitation and Folsom received 5.85 inches within the same 24-hour period. However, other areas of the Sacramento River Basin were not affected as severely as the Sacramento metropolitan area. Marysville, only 40 miles north of Sacramento, received only 1.0 inches of rainfall during the 24-hour period.

The January storms more severely affected northern California, while the March storms concentrated more of their impact on central/southern California. Fresno and Coalinga set 24-hour rainfall records on March 10, receiving 2.38 inches and 3.74 inches, respectively. Since the average annual rainfall for Coalinga is only 7.85 inches, the City received nearly 50 percent of its average annual precipitation in a 24-hour period. During March 1995, most locations in the southern San Joaquin River and Tulare Lake basins received several times their normal March precipitation, including: Bakersfield, 326 percent; Coalinga, 603 percent; Five Points, 474 percent; Fresno, 311 percent; Hanford, 356 percent; and Visalia, 397 percent.

Both January and March, showed much above-normal precipitation over most of the State. Since most of the storms occurred within relatively cool, unstable air masses, much of the precipitation above elevation 5,000 feet accumulated as snow. Water content of snowpack exceeded 150 percent of normal in much of the Sacramento Basin and Sierra Nevada at the end of March. Stream gaging stations that exceeded previous peak flows are shown in Table 5-23.

## TABLE 5-22
## MAJOR STORMS IN WATER YEAR 1995 AND PRECIPITATION TOTALS FOR SELECTED LOCATIONS

| Location | Date | Precipitation (inches) | River Basin |
|---|---|---|---|
| **January 1995 Storms** | | | |
| Brandy Creek | January 8-9 (48 hr) | 17.36 | Sacramento River |
| Redding | January 1-16 | 14.87 | Sacramento River |
| Mount Shasta | January 9 (24 hr) | 5.76 | Sacramento River |
| | January 1-16 | 22.81 | Sacramento River |
| Blue Canyon | January 10 (24 hr) | 5.05 | American River |
| | January 8-14 | 28.16 | American River |
| Sacramento | January 10 (24 hr) | 4.45 | American River |
| | January 1-16 | 9.39 | American River |
| **March 1995 Storm** | | | |
| Mount Shasta | March 7-11 | 8.31 | Sacramento River |
| Blue Canyon | March 7-11 | 10.72 | American River |
| | March 19-23 | 7.59 | American River |
| Coalinga | March 10 (24 hour) | 3.74 | Tulare Lake Basin |
| | March 9-10 | 4.43 | Tulare Lake Basin |
| Five Points | March 10 | 1.45 | Tulare Lake Basin |
| Fresno | March 10 (24 hour) | 2.38 | San Joaquin River |
| | March 9-10 | 3.17 | San Joaquin River |
| Corcoran | March 10-11 | 2.75 | Tulare Lake Basin |
| Visalia | March 11 | 1.32 | Tulare Lake Basin |

## OPERATIONAL CONSTRAINTS

Rainfall in December 1994 was just slightly below normal and early January 1995 was well above normal for most of the Sacramento and San Joaquin River basins. By January 7, Sacramento had received 10.43 inches of rainfall in comparison to the normal 8.02 inches. However, most of the major projects in the Sacramento and San Joaquin River basins were less than half full and only 75 percent of normal after the relatively dry 1994 water year and an extended drought from 1987 through 1992. Flood management reservation pools for the three major projects in the Sacramento River Basin ranged from 181 percent for Folsom Lake to 247 percent for Oroville Lake. Over 100 percent of the flood management reservation pool was available for all of the major San Joaquin River projects.

As of March 1, 1995, the available flood management reservation pool varied greatly between projects in the Sacramento and San Joaquin River basins. In the Sacramento Basin, the available flood management reservation pool ranged from 65 percent for Black Butte Lake to 141 percent for New Bullards Bar Lake. Variable flood management reservation conditions were also present in the San Joaquin River basin as only 50 percent of the flood management reservation pool was available at Millerton Lake while over 381 percent of the flood management reservation pool was available at New Melones Lake.

During January, flooding in the Sacramento River Basin below Shasta Dam was mainly attributed to failure of storm drainage systems and small streams. The inflow to Shasta Dam, which peaked in excess of 100,000 cfs, was almost entirely stored. Runoff from major Sierra rivers was also mostly stored by reservoirs. The maximum release from Folsom Dam was only 30,000 cfs, and releases from Oroville Dam to the Feather River were only 5,000 cfs later in the storm.

None of the major reservoirs in the Sacramento River Basing greatly infringed on their flood management reservation pool during the January 1995 floods. The major reservoirs in the San Joaquin River Basin demonstrated similar operations, as over 70 percent of the flood management reservation pool remained in all the reservoirs after the January event. At the end of the January event 73 percent of the flood management reservation pool remained in Millerton Lake, while 404 percent of the flood management reservation pool remained for New Melones Lake.

During the March event, the available flood management storage pooled varied greatly between projects in the Sacramento and San Joaquin River basins. Only 21 percent of the flood management reservation pool was available at Shasta Lake during the March event, and Black Butte Reservoir reached design capacity. In comparison, both Folsom Lake and New Bullards Bar Lake had over 88 percent of their flood management reservation pool available at the end of the March event. Similar variation between reservoirs also occurred in the San Joaquin River basin, as only 4 percent of the flood management reservation pool remained at Millerton Lake during the peak of the March event while 315 percent of the flood management reservation pool remained at New Melones Lake. Tables 5-24 and 5-25 summarize peak storage conditions during the 1995 January and March floods.

**TABLE 5-23**
**PEAK FLOWS FOR STREAM GAGES THAT EQUALED OR EXCEEDED PREVIOUS MAXIMUMS DURING 1995**

| Station | Previous Date | Maximum Flow (cfs) | 1995 Maximum Flow (cfs) |
|---|---|---|---|
| Del Puerto Creek near Patterson | 1959 | 1,800 | 3,400 |
| Cache Creek near Yolo | 1958 | 41,400 | 36,400 |
| Note: 1995 Maximum flows from USGS | | | |

## AREAS AFFECTED BY FLOODING

Table 5-26 lists the areas that flooded during the 1995 floods in the Sacramento and San Joaquin River basins. The flooding mainly occurred on small streams. The extent of flooding due to small stream flooding as well as local flooding is shown on Figure 5-5 and Figures 5-6a through 5-6L. The flood extent information was determined from aerial photography taken in mid-January and mid-March, along with other sources.

## DAMAGES SUSTAINED

Tables 5-27 and 28 show damages by county from the flooding in 1995 in the Sacramento River Basin and the San Joaquin River Basin, respectively. The damage categories are individual, public, business, and agricultural. Individual damages consist of damage to residences, outbuildings, and personal property. Public damages consist of damages to public buildings and infrastructure. Business damages consist of damage to business structures, inventory, fixtures, and equipment. Individual, business, and public damages were compiled by the OES and were retrieved from the OES database, the only available data source for this flooding. Agricultural damages consist of losses to crops, livestock, and nurseries. Agricultural damage data were derived from a newsletter published by the California Department of Food and Agriculture, the most complete source available for this flood. All damages are reported in 1995 dollars.

## DAMAGES PREVENTED

Damages prevented by flood management operations during the 1995 floods in the Sacramento and San Joaquin River basins are shown in Tables 5-29 and 5-30, respectively. Damages prevented are reported in 1995 dollars. The pre and postproject flows in the tables illustrate the reduction in peak flows resulting from operation of the flood management system for the event. Appendix D includes hydrographs for each event that indicate the impact of the flood management system on the flood hydrograph at selected points in the basins.

## TABLE 5-24
## STORAGE CONDITIONS FOR PROJECTS DURING JANUARY 1995 RAIN FLOODS

| Project | Storage Capacity | | As of January 1 | | January Flood | |
|---|---|---|---|---|---|---|
| | Total Storage (TAF[1]) | Flood Mgmt Storage (TAF[1]) | Total Storage (TAF[1]) | Flood Mgmt Storage Avail. | Total Storage (TAF[1]) | Flood Mgmt Storage Remain |
| **Sacramento River Basin** | | | | | | |
| Shasta Dam and Lake | 4,552 | 1,300 | 2,044 | 193% | 3,406 | 88% |
| Black Butte Dam and Lake | 144 | 136 | 20 | 91% | 123 | 15% |
| Oroville Dam and Lake | 3,538 | 750 | 1,684 | 247% | 2,708 | 111% |
| New Bullards Bar Dam and Lake | 966 | 170 | 530 | 256% | 784 | 107% |
| Folsom Dam and Lake | 977 | 400 | 253 | 181% | 588 | 97% |
| **San Joaquin River Basin** | | | | | | |
| Friant Dam and Millerton Lake | 521 | 170 | 219 | 178% | 397 | 73% |
| Hidden Dam and Hensley Lake | 90 | 65 | 8 | 126% | 38 | 80% |
| Buchanan Dam and Eastman Lake | 150 | 45 | 29 | 269% | 63 | 193% |
| New Exchequer Dam and Lake McClure | 1,025 | 400 | 282 | 186% | 467 | 140% |
| Don Pedro Dam and Lake | 2,030 | 340 | 1,412 | 182% | 1,671 | 106% |
| New Melones Dam and Lake | 2,420 | 450 | 426 | 443% | 600 | 404% |
| **Eastside Tributaries** | | | | | | |
| Farmington Dam and Lake | 52 | 52 | 0 | 100% | 24 | 54% |
| New Hogan Dam and Lake | 317 | 165 | 30 | 174% | 135 | 110% |
| Camanche Dam and Lake | 430 | 200 | 205 | 113% | 247 | 92% |
| **Tulare Lake Basin** | | | | | | |
| Isabella Dam and Lake | 568 | 398 | 116 | 114% | 141 | 107% |
| Success Dam and Lake | 82 | 75 | 9 | 97% | 13 | 92% |
| Terminus Dam and Lake Kaweah | 143 | 142 | 6 | 96% | 8 | 95% |
| Pine Flat Dam and Lake | 1,000 | 475 | 206 | 167% | 365 | 134% |

Notes:
1 Storage values rounded to nearest 1,000 acre-feet

## TABLE 5-25
## STORAGE CONDITIONS FOR PROJECTS DURING MARCH 1995 RAIN FLOODS

| Project | Storage Capacity | | As of March 1 | | March Flood | |
|---|---|---|---|---|---|---|
| | Total Storage (TAF[1]) | Flood Mgmt Storage (TAF[1]) | Total Storage (TAF[1]) | Flood Mgmt Storage Avail. | Total Storage (TAF[1]) | Flood Mgmt Storage Remain |
| **Sacramento River Basin** | | | | | | |
| Shasta Dam and Lake | 4,552 | 1,300 | 3,459 | 84% | 4,284 | 21% |
| Black Butte Dam and Lake | 144 | 136 | 55 | 65% | 146 | -1% |
| Oroville Dam and Lake | 3,538 | 750 | 2,650 | 118% | 3,008 | 71% |
| New Bullards Bar Dam and Lake | 966 | 170 | 726 | 141% | 817 | 88% |
| Folsom Dam and Lake | 977 | 400 | 572 | 101% | 625 | 88% |
| **San Joaquin River Basin** | | | | | | |
| Friant Dam and Millerton Lake | 521 | 170 | 436 | 50% | 515 | 4% |
| Hidden Dam and Hensley Lake | 90 | 65 | 43 | 72% | 77 | 20% |
| Buchanan Dam and Eastman Lake | 150 | 45 | 72 | 173% | 133 | 38% |
| New Exchequer Dam and Lake McClure | 1,025 | 400 | 528 | 124% | 755 | 68% |
| Don Pedro Dam and Lake | 2,030 | 340 | 1,624 | 119% | 1,860 | 50% |
| New Melones Dam and Lake | 2,420 | 450 | 704 | 381% | 1,002 | 315% |
| **Eastside Tributaries** | | | | | | |
| Farmington Dam and Lake | 52 | 52 | 0 | 100% | 21 | 60% |
| New Hogan Dam and Lake | 317 | 165 | 148 | 102% | 250 | 41% |
| Camanche Dam and Lake | 430 | 200 | 245 | 93% | 328 | 51% |
| **Tulare Lake Basin** | | | | | | |
| Isabella Dam and Lake | 568 | 398 | 170 | 100% | 267 | 76% |
| Success Dam and Lake | 82 | 75 | 16 | 88% | 45 | 49% |
| Terminus Dam and Lake Kaweah | 143 | 142 | 7 | 96% | 71 | 51% |
| Pine Flat Dam and Lake | 1,000 | 475 | 482 | 109% | 802 | 42% |

Notes:
1 Storage values rounded to nearest 1,000 acre-feet

## TABLE 5-26
## AREAS AFFECTED BY FLOODING DURING 1995 RAIN FLOODS

| Stream | Area | Description |
|---|---|---|
| **Sacramento River Basin** | | |
| Dry Creek | Roseville and Rio Linda | Overflowed, inundating 250/300 homes |
| Arcade Creek | Sacramento | Overflowed, threatening 20 homes. |
| Morrison Creek | Sacramento | City pump failure, inundating 300 homes from local drainage. |
| Sacramento River | Hamilton City | Private levee failure. |
| **San Joaquin River Basin** | | |
| Firebaugh Canal | Fresno County | East levee breached in two places |
| San Joaquin River | RD 2100 and RD 2102 | Levee breach |
| Arroyo Pasajero | Fresno County near Coalinga | 100-ft span of I-5 bridge collapsed; 6 people killed |
| **Tulare Lake Basin** | | |
| Kings River/Cole Slough | Fresno and Kings Counties | North levee failed[1] |
| Notes:<br>1 Levee failed during snowmelt runoff due to elevated releases caused by infringement into snowmelt flood management reservation in Pine Flat from March rainstorms. | | |

## TABLE 5-27
## 1995 RAIN FLOOD DAMAGES BY COUNTY FOR THE SACRAMENTO VALLEY
## ($1,000)[1]

| County | Individual Damages[2] | Public Damages[2] | Business Damages[2] | Agricultural Damages[3] | Total by County |
|---|---|---|---|---|---|
| Butte | $800 | $3,200 | $3,300 | $50,000 | **$57,300** |
| Colusa | $4,800 | $1,100 | $1,100 | $5,374 | **$12,374** |
| Glenn | $20 | $1,000 | $30 | $48,575 | **$49,625** |
| Placer | $74,000 | $11,100 | $1,400 | $35 | **$86,535** |
| Sacramento | $40 | $7,500 | $20 | $12,450 | **$20,010** |
| Shasta | $40 | $5,300 | ----- | $293 | **$5,633** |
| Solano | $220 | $2,500 | $890 | $2,008 | **$5,618** |
| Sutter | $50 | $10,700 | $110 | $14,038 | **$24,898** |
| Tehama | $210 | $2,800 | $180 | $18,354 | **$21,544** |
| Yolo | $20 | $6,500 | $0 | $4,516 | **$11,036** |
| Yuba | $200 | $2,900 | $120 | $8,131 | **$11,351** |
| **Totals** | **$80,400** | **$54,600** | **$7,150** | **$163,774** | **$305,924** |

Notes:
1 All damages are in 1995 dollars.
2 California Governor's Office of Emergency Services database.
3 California Department of Food and Agriculture, 1995.

## TABLE 5-28
## 1995 FLOOD DAMAGES BY COUNTY FOR THE SAN JOAQUIN VALLEY
## ($1,000)[1]

| County | Individual Damages[2] | Public Damages[2] | Business Damages[2] | Agricultural Damages[3] | Total by County |
|---|---|---|---|---|---|
| Fresno | $80 | $300 | $10 | $20,846 | **$21,236** |
| Kern | $10 | $1,900 | $10 | $21,046 | **$22,966** |
| Kings | ----- | ----- | ----- | $2,484 | **$2,484** |
| Madera | $160 | $1,300 | $10 | $829 | **$2,299** |
| Merced | ----- | ----- | ----- | $38,854 | **$38,854** |
| San Joaquin | ----- | ----- | ----- | $4,499 | **$4,499** |
| Stanislaus | ----- | ----- | ----- | $52,447 | **$52,447** |
| Tulare | ----- | ----- | ----- | $48,515 | **$48,515** |
| **Totals** | **$250** | **$3,500** | **$30** | **$189,520** | **$193,300** |

Notes:
1 All damages are in 1995 dollars.
2 California Governor's Office of Emergency Services database.
3 California Department of Food and Agriculture, 1995.

## TABLE 5-29
## DAMAGES PREVENTED DURING 1995 RAIN FLOODS IN SACRAMENTO VALLEY

| Project | Preproject Flow (cfs) | Postproject Flow (cfs) | Damages Prevented ($1,000)[1] |
|---|---|---|---|
| **Sacramento River Basin** | | | |
| Shasta Dam and SRFCP | 132,600 | 68,200 | $0 |
| Shasta Dam and SRFCP (updated)[2] | 132,600 | 68,200 | $3,499,000 |
| Black Butte Dam | 35,300 | 15,100 | $24,000 |
| **Feather River Basin** | | | |
| Oroville Dam | 101,000 | Nondamaging[3] | $12,100 |
| New Bullards Bar Dam | Nondamaging[3] | Nondamaging[3] | $0 |
| **American River Basin** | | | |
| Folsom Dam and American River Levees | 74,500 | 41,700 | $0 |
| Folsom Dam and American River Levees (updated)[2] | 74,500 | 41,700 | $5,700 |
| **TOTAL 1995 Sacramento Valley** | | | **$3,540,800** |

Notes:
1 Damages prevented are in 1995 dollars.
2 Damages prevented updated based on new flow/damage relationships.
3 Actual flow was never reported but was less than the lowest damaging flow.

## TABLE 5-30
## DAMAGES PREVENTED DURING 1995 RAIN FLOODS
## IN SAN JOAQUIN VALLEY

| Project | Preproject Flow (cfs) | Postproject Flow (cfs) | Damages Prevented ($1,000)[1] |
|---|---|---|---|
| **San Joaquin River Basin** | | | |
| Lower San Joaquin River Levees[5] | | | $583 |
| Friant Dam | 52,100 | 14,800 | $54,310 |
| Hidden Dam | 8,600 | 3,000 | $2,200 |
| Buchanan Dam | 8,000 | 1,600 | $1,800 |
| Merced County Streams[5] | | | $2,400 |
| New Exchequer Dam | 38,200 | 7,800 | $25,700 |
| Don Pedro Dam | 36,700 | 12,000 | $19,500 |
| New Melones Dam | 19,100 | 3,500 | $2,100 |
| **Eastside Tributaries** | | | |
| Farmington Dam, Littlejohn and Duck Creeks | 5,300 | Nondamaging[3] | $4,000 |
| New Hogan Dam | 19,600 | 2,200 | $2,100 |
| New Hogan Dam (updated data)[2] | 19,600 | 2,200 | $10,400 |
| Camanche Dam | 11,100 | 4,000 | $3,000 |
| **Tulare Lake Basin** | | | |
| Isabella Dam[4] | 8,600 | 3,800 | $140 |
| Success Dam[4] | 8,400 | 800 | $0 |
| Terminus Dam[4] | 12,700 | 4,600 | $800 |
| Pine Flat Dam[4] | 40,900 | 13,300 | $29,100 |
| **TOTAL 1995 San Joaquin Valley** | | | **$184,886** |

Notes:
1 Damages prevented are in 1995 dollars.
2 Damages prevented updated based on new flow/damage relationships.
3 Actual flow was never reported but was less than the lowest damaging flow.
4 Damages prevented for these reservoirs include values from the Tulare Lakebed and are not just determined by individual river flows.
5 Multiple index points; individual flows not shown.

## FLOOD OF 1997

### DESCRIPTION OF STORMS

A majority of the flooding in early January 1997 resulted from a trio of subtropical storms. Over a 3-day period, warm moist winds from the southwest blowing over the Sierra Nevada poured more than 30 inches of rain onto watersheds that were already saturated by one of the wettest Decembers on record. The first of the storms hit Northern California on December 29, 1996, with less than expected precipitation totals. Only 0.24 inch of rainfall was reported in Sacramento. On December 30, the second storm arrived. The third and most severe storm hit late December 31 and lasted through January 2.

Precipitation totals at lower elevations in the Central Valley were not unusually high, in contrast to extreme rainfall in the upper watersheds. Downtown Sacramento, for example, received 3.7 inches of rain from December 26, 1996, through January 2, 1997. However, Blue Canyon (elevation 5,000 feet) in the American River Basin received over 30 inches of rainfall, thus providing for an orographic ratio of 8 to 1. A typical storm for this region would yield an orographic ratio of between 3 to 4 between these two locations. Precipitation totals for the event are shown in Table 5-31. Extreme precipitation in the Sierra Nevada resulted in record flows in both the Sacramento and San Joaquin River basins. Several gaging stations used to measure the water level in streams and rivers recorded the largest peaks in the history of their operation during this series of storms, as shown in Table 5-32.

In addition to the trio of subtropical storms, snowmelt also contributed to the already large runoff volumes. Several days before Christmas 1996, a cold storm from the Gulf of Alaska brought snow to low elevations in the Sierra Nevada foothills. Blue Canyon, for example, had a snowpack with 5 inches of water content. The snowpack at Blue Canyon, as well as the snowpack at lower elevations, melted when the trio of warmer storms hit. Not much snowpack loss was observed, however, at snow sensors over 6,000 feet in elevation in the northern Sierra. The effect of the snowmelt was estimated to contribute approximately 15 percent to runoff totals.

### OPERATIONAL CONSTRAINTS

Prior to the late December storms, rainfall was already well above normal throughout the Sacramento and San Joaquin River basins. In the northern Sierra, total December precipitation exceeded 28 inches, the second wettest December of record, exceeded only by the 30.8 inches in December 1955. Most of the reservoirs in these basins were already at or above desired flood management levels before the storms. Flood management storage in Shasta, Folsom, New Melones, Don Pedro, McClure and Millerton Lakes was already in use at the onset of the late December storms. As of December 1, however, most of the major reservoirs in both the Sacramento and San Joaquin River basins were at normal flood management reservation levels (100 percent of the flood management reservation space was available).

The San Joaquin River flood management system was pushed beyond its limits during the 1997 flood. Millerton Lake and Don Pedro Reservoir, two of the major projects in the San Joaquin

## TABLE 5-31
## TOTAL PRECIPITATION, DECEMBER 20, 1996 - JANUARY 3, 1997

| Location | Precipitation (inches) | River Basin |
|---|---|---|
| Bakersfield | 1.11 | Kern River |
| Blue Canyon | 39.34 | American River |
| Brush Creek | 37.04 | American River |
| Fresno | 3.08 | San Joaquin River |
| Mc Cloud Ranger Station | 14.83 | Sacramento River |
| Mount Shasta | 10.06 | Sacramento River |
| Paradise Fire Station | 22.66 | Feather River |
| Sacramento | 5.67 | American River |
| Strawberry Valley | 37.41 | Feather River |
| Success Dam | 3.36 | Tule River |

## TABLE 5-32
## PEAK FLOWS FOR STREAM GAGES THAT EQUALED OR EXCEEDED PREVIOUS MAXIMUMS DURING 1997

| Stream Gage | Drainage Area (sq mi) | Previous Date | Maximum Flow (cfs) | 1997 Maximum Flow (cfs) |
|---|---|---|---|---|
| Tuolumne River at Modesto | 1884 | 1950 | 57,000 | 55,800 |
| Cosumnes River at Michigan Bar | 536 | 1986 | 45,000 | 93,000 |
| South Fork American River near Placerville | 598 | 1964 | 47,300 | 71,000 |
| South Fork American River near Camino | 493 | 1955 | 49,800 | 62,300 |
| South Fork Mokelumne River near West Point | 75.1 | 1986 | 7,300 | 7,600 |

River Basin, exceeded their design capacity. At Don Pedro, the peak hourly inflow reached 121,000 cfs, and the peak hourly outflow climbed to 59,000 cfs, while at Millerton the peak hourly inflow and outflow were 95,000 cfs and 63,000 cfs, respectively. In addition, only 29 percent of the flood management reservation remained in New Melones and only 4 percent of the flood management reservation pool remained in Lake McClure.

Similar, but not quite as severe, capacities were reached in the Sacramento River Basin. New Bullards Bar Lake nearly reached design capacity as only 1 percent of the flood management reservation pool remained at the peak of the flood. Both Oroville and Shasta came close to reaching design capacity. Only 11 percent of the flood management reservation pool remained at Lake Shasta while only 27 percent remained at Lake Oroville. Massive releases were made at both dams to accommodate peak inflows of 215,000 cfs at Shasta Lake and 277,000 at Lake Oroville. The corresponding releases were 79,000 cfs from Shasta Lake and 160,000 cfs from Lake Oroville. Folsom Lake experienced a peak inflow of 255,000 cfs and was able to control it to the objective release of 115,000 cfs, with 28 percent of the flood management storage available at the peak of the storm. Storage capacities in major reservoirs during the 1997 floods are summarized in Table 5-33.

## AREAS AFFECTED BY FLOODING

Table 5-34 lists the levee breaks and areas that flooded during the 1997 flood in the Sacramento and San Joaquin valleys. As indicated, there were numerous levee breaks in both valleys, often with multiple breaks along a section of levee. The extent of flooding that resulted from these breaks is shown on Figure 5-7 and Figures 5-8a through 5-8L. The flood extent was determined from aerial photography taken in January, along with other sources.

## DAMAGES SUSTAINED

Tables 5-35 and 5-37 summarize damages by county from flooding in 1997 in the Sacramento Valley and San Joaquin Valley, respectively. The damage categories consist of individual, public, business, roads and bridges, and agricultural. Individual damages consist of damage to residences, outbuildings, and personal property. Public damages consist of damages to public buildings and infrastructure. Business damages consist of damage to business structures, inventory, fixtures, and equipment. Agricultural damages consist of losses to crops, livestock, and nurseries. Individual, public, and business damages were compiled by OES and were retrieved from the OES database, a more recent collection of data than in the small communities' flood assessments. Agricultural damages were taken from the California Department of Food and Agriculture Internet web site.

Tables 5-36 and 5-38 identify the number of residences, mobile homes, and businesses damaged during the 1997 flood in the Sacramento Valley and San Joaquin Valley, respectively. The tables also indicate whether roads and bridges were damaged. The number of damaged residences, mobile homes, and businesses was derived from California Winter Storms (DWR #1155), one of two available data sources for this flood. This publication was also used in the small communities' flood assessments. Information regarding damages to roads and bridges was derived from the small communities' flood assessments of the Sacramento and San Joaquin River basins.

## TABLE 5-33
## STORAGE CONDITIONS FOR PROJECTS DURING 1997 RAIN FLOODS

| Project | Storage Capacity | | As of December 1 | | Event | |
|---|---|---|---|---|---|---|
| | Total Storage (TAF[1]) | Flood Mgmt Storage (TAF[1]) | Total Storage (TAF[1]) | Flood Mgmt Storage Avail. | Total Storage (TAF[1]) | Flood Mgmt Storage Remain |
| **Sacramento River Basin** | | | | | | |
| Shasta Dam and Lake | 4,552 | 1,300 | 3,189 | 105% | 4,414 | 11% |
| Black Butte Dam and Lake | 144 | 136 | 39 | 77% | 112 | 24% |
| Oroville Dam and Lake | 3,538 | 750 | 2,723 | 109% | 3,332 | 27% |
| New Bullards Bar Dam and Lake | 966 | 170 | 608 | 211% | 965 | 1% |
| Folsom Dam and Lake | 977 | 400 | 564 | 103% | 864 | 28% |
| **San Joaquin River Basin** | | | | | | |
| Friant Dam and Millerton Lake | 521 | 170 | 284 | 139% | 527 | -4% |
| Hidden Dam and Hensley Lake | 90 | 65 | 28 | 95% | 66 | 37% |
| Buchanan Dam and Eastman Lake | 150 | 45 | 90 | 133% | 142 | 18% |
| New Exchequer Dam and Lake McClure | 1,025 | 400 | 671 | 89% | 1,009 | 4% |
| Don Pedro Dam and Lake | 2,030 | 340 | 1,680 | 103% | 2,046 | -5% |
| New Melones Dam and Lake | 2,420 | 450 | 1,990 | 96% | 2,291 | 29% |
| Farmington Dam and Lake | 52 | 52 | 0 | 100% | 25 | 52% |
| New Hogan Dam and Lake | 317 | 165 | 144 | 105% | 227 | 55% |
| Camanche Dam and Lake | 430 | 200 | 317 | 56% | 420 | 5% |
| **Tulare Lake Basin** | | | | | | |
| Isabella Dam and Lake | 568 | 398 | 246 | 81% | 435 | 33% |
| Success Dam and Lake | 82 | 75 | 18 | 85% | 72 | 13% |
| Terminus Dam and Lake Kaweah | 143 | 142 | 15 | 90% | 115 | 20% |
| Pine Flat Dam and Lake | 1,000 | 475 | 440 | 118% | 912 | 19% |

Notes:
1 Storage values rounded to nearest 1,000 acre-feet

## TABLE 5-34
## AREAS AFFECTED BY FLOODING DURING 1997 RAIN FLOOD

| Stream | Area | Description |
|---|---|---|
| **Sacramento Valley** | | |
| Butte Creek | State Maintenance Area 5 | Both levees overtopped. West levee failed. |
| Deer Creek | Tehama County | Levee breaks on both levees |
| Elder Creek | Tehama County | Levee break on the south levee |
| Feather River | RD 784 | East levee failed near town of Arboga |
| Bear River | RD 784 | North levee failed in two places |
| Dry Creek (Yuba City) | RD 817 | South bank overtopped |
| Sutter Bypass | RD 1660, RD 70, town of Meridian | West levee failed, flooding RDs 1660 and 70 |
| **San Joaquin Valley** | | |
| San Joaquin River | Lower San Joaquin Levee District | North levee failed in seven places in Madera County; south levee failed in four places in Fresno County; levee overtopped upstream from Chowchilla Canal Bypass |
| San Joaquin River/ Stanislaus River | RD 2064 | East levee failed in two places |
| San Joaquin River | RD 2075 | East levee failed in three places |
| San Joaquin River | RD 2094 | East levee breached in four places; water from RD 2094 break flooded RD 2096 |
| San Joaquin River | RD 2101 | West levee failed in three places, inundating RD 2099, RD 2100, RD 2101, and RD 2102) |
| San Joaquin River | RD 2099 | West levee failed (spur levee) |
| San Joaquin River | RD 2100 | East levee failed in two locations |
| San Joaquin River | RD 2096 | East levee failed, mouth of Walthall Slough |
| San Joaquin River | RD 2091 | Spur levee failed |
| Tuolumne River | Modesto, Waterford, La Grange, & Roberts Ferry | Bank overtopped due to high flows from Don Pedro |
| Cosumnes River | Wilton | Four breaks; 1 overtopping - private levees |
| Cosumnes River | Sacramento and San Joaquin Counties | Numerous breaks and overtopping of private levees |
| San Joaquin River | RD 2031 | East levee failed in two places |
| Finnegan Cut | RD 2031 | East levee failed |
| **Sacramento - San Joaquin River Delta** | | |
| Paradise Cut | RD 2107 | East levee break floods RDs 2062 and 2107 |
| Paradise Cut | RD 2095 | Partially inundated when south levee failed |
| Tom Paine Slough | RD 2058 | Partially flooded by overflow of unleveed Tom Paine Slough |
| Prospect Island | Prospect Island | Multiple levee breaks |

## TABLE 5-35
## 1997 RAIN FLOOD DAMAGES BY COUNTY
## FOR THE SACRAMENTO VALLEY
## ($1,000)[1]

| County | Individual Damages[2] | Public Damages[2] | Business Damages[2] | Roads & Bridges Damages[3] | Agricultural Damages[4] | Total by County |
|---|---|---|---|---|---|---|
| Butte | $4,100 | $2,800 | $1,000 | $26,500 | $1,000 | **$35,400** |
| Colusa | $200 | $470 | $0 | $122 | $552 | **$1,344** |
| Glenn | $530 | $1,700 | $20 | $1,262 | $627 | **$4,139** |
| Placer | $5,000 | $2,400 | $5,000 | $628 | ----- | **$13,028** |
| Sacramento | $13,360 | $5,000 | $1,000 | $4,500 | $7,915 | **$31,775** |
| Shasta | $310 | $1,200 | $200 | $4,770 | $175 | **$6,655** |
| Solano | $9,570 | $3,000 | $0 | minimal | $2,393 | **$14,963** |
| Sutter | $10,020 | $16,300 | $10,000 | $25 | $4,214 | **$40,559** |
| Tehama | $470 | $840 | $300 | $400 | $446 | **$2,456** |
| Yolo | $0 | $220 | $0 | $200 | $1,889 | **$2,309** |
| Yuba | $58,000 | $7,900 | $35,000 | $71 | $47,060 | **$148,031** |
| **Totals** | **$101,560** | **$41,830** | **$52,520** | **$38,478** | **$66,271** | **$300,659** |

Notes:
1 Damages are in 1997 dollars.
2 California Governor's Office of Emergency Services database.
3 Corps, 1997a.
4 California Department of Food and Agriculture, 1998.

## TABLE 5-36
## 1997 RAIN FLOODING OF RESIDENCES, MOBILE HOMES, BUSINESSES, ROADS, AND BRIDGES IN THE SACRAMENTO VALLEY

| County | Residences Damaged[1] | Mobile Homes Damaged[1] | Businesses Damaged[1] | Roads Damaged?[2] | Bridges Damaged?[2] |
|---|---|---|---|---|---|
| Butte | 250 | 73 | 320 | yes | yes |
| Colusa | 6 | 0 | 0 | yes | ----- |
| Glenn | 55 | 9 | 1 | yes | ----- |
| Placer | 137 | 0 | 22 | yes | ----- |
| Sacramento | 2,495 | 172 | 29 | yes | ----- |
| Shasta | 10 | 1 | 7 | yes | ----- |
| Solano | 1,466 | 118 | 1 | yes | ----- |
| Sutter | 1,280 | 30 | 600 | yes | ----- |
| Tehama | 24 | 6 | 20 | yes | yes |
| Yolo | 0 | 0 | 0 | yes | ----- |
| Yuba | 700 | 80 | 30 | yes | ----- |
| **Totals** | **6,423** | **489** | **1,030** | **yes** | **yes** |

Notes:
1 California Governor's Office of Emergency Services, 1997.
2 Corps, 1997a.

## TABLE 5-37
## 1997 RAIN FLOOD DAMAGES BY COUNTY
## FOR THE SAN JOAQUIN VALLEY
## ($1,000)[1]

| County | Individual Damages[2] | Public Damages[2] | Business Damages[2] | Road & Bridge | Agricultural Damages[3] | Total by County |
|---|---|---|---|---|---|---|
| Fresno | $620 | $3,400 | $0 | ----- | $1,394 | **$5,414** |
| Kern | ----- | ----- | ----- | ----- | ----- | **-----** |
| Kings | ----- | ----- | ----- | ----- | $38,857 | **$38,857** |
| Madera | $1,400 | $270 | $20 | ----- | $2,497 | **$4,187** |
| Merced | $0 | $570 | $0 | n/a | $7,610 | **$8,180** |
| San Joaquin | $46,500 | $9,500 | $10,000 | n/a | $13,455 | **$79,455** |
| Stanislaus | $20,680 | $23,200 | $3,650 | ----- | $30,832 | **$78,362** |
| Tulare | $1,500 | $770 | $500 | n/a | $6,066 | **$8,836** |
| **Totals** | **$70,700** | **$37,710** | **$14,170** | **-----** | **$100,711** | **$223,291** |

Notes:
1 Damages are in 1997 dollars.
2 California Governor's Office of Emergency Services database.
3 California Department of Food and Agriculture, 1998.

## TABLE 5-38
## 1997 RAIN FLOODING OF RESIDENCES, MOBILE HOMES, BUSINESSES, ROADS, AND BRIDGES IN THE SAN JOAQUIN VALLEY

| County | Residences Damaged[1] | Mobile Homes Damaged[1] | Businesses Damaged[1] | Roads Damaged?[2] | Bridges Damaged?[2] |
|---|---|---|---|---|---|
| Fresno | 65 | 4 | 22 | ----- | ---- |
| Kern | ----- | ----- | ----- | ----- | ---- |
| Kings | ----- | ----- | ----- | ----- | ---- |
| Madera | 63 | 29 | 4 | ----- | ---- |
| Merced | 0 | 0 | 0 | yes | yes |
| San Joaquin | 335 | 254 | 7 | yes | ---- |
| Stanislaus | 1,072 | 145 | 29 | ----- | ---- |
| Tulare | 167 | 6 | 13 | yes | ---- |
| TOTAL | **1,702** | **438** | **75** | **yes** | **yes** |

Notes:
1 California Governor's Office of Emergency Services, 1997.
2 Corps, 1997b.

## DAMAGES PREVENTED

Tables 5-39 and 5-40 summarize damages prevented by flood management operations during the 1997 floods in the Sacramento and San Joaquin valleys. Damages prevented are given in 1997 dollars. The pre and postproject flows in the tables illustrate the reduction in peak flows resulting from operation of the flood management system for the event. Appendix E includes hydrographs for each event that indicate the impact of the flood management system on the flood hydrograph at selected points in the basins.

### TABLE 5-39
### DAMAGES PREVENTED DURING 1997 RAIN FLOODING IN SACRAMENTO VALLEY

| Project | Pre-Project Flow (cfs) | Post-Project Flow (cfs) | Damages Prevented ($1,000)[1] |
|---|---|---|---|
| **Sacramento River Basin** | | | |
| Shasta Dam and SRFCP | 237,000 | 79,000 | $198,000 |
| Shasta Dam and SRFCP (updated)[2] | 237,000 | 79,000 | $4,267,000 |
| Black Butte Dam | 36,100 | 15,500 | $24,950 |
| **Feather River Basin** | | | |
| Oroville Dam and Feather River Levees | | | |
| Flow at Dam | 302,000 | 160,000 | $1,058,440 |
| Above Yuba River | 312,000 | 160,000 | |
| Below Yuba River | 530,000 | 315,000 | |
| New Bullards Bar Dam | 107,000 | 55,000 | $4,420 |
| **American River Basin** | | | |
| Folsom Dam and American River Levees | 253,000 | 115,000 | $773,560 |
| Folsom Dam and American River Levees (updated)[2] | 253,000 | 115,000 | $15,062,000 |
| **TOTAL 1997 Sacramento Valley** | | | **$20,416,810** |

Notes:
1 Damages prevented are in 1997 dollars
2 Damages prevented updated based on new flow/damage relationships

## TABLE 5-40
## DAMAGES PREVENTED DURING 1997 RAIN FLOOD IN SAN JOAQUIN VALLEY

| Project | Pre-Project Flow (cfs) | Post-Project Flow (cfs) | Damages Prevented ($1,000)[1] |
|---|---|---|---|
| **San Joaquin River Basin** | | | |
| Lower San Joaquin River Levees[4] | | | |
| Friant Dam | 90,000 | 60,000 | $3,320 |
| Hidden Dam | 13,000 | 4,600 | $5,670 |
| Buchanan Dam | 14,500 | 6,000 | $2,180 |
| Merced County Streams[4] | | | $27,500 |
| New Exchequer Dam | 90,000 | 8,000 | $86,210 |
| Don Pedro Dam | 110,000 | 56,000 | $30,690 |
| New Melones Dam | 80,000 | 7,000 | $175,770 |
| **Eastside Tributaries** | | | |
| Farmington Dam, Littlejohn and Duck Creeks | 13,300 | 1,900 | $19,000 |
| New Hogan Dam | 23,900 | 7,000 | $21,410 |
| New Hogan Dam (updated data)[2] | 23,900 | 7,000 | $19,700 |
| Mormon Slough | 30,600 | 7,800 | $94,210 |
| Mormon Slough (updated data)[2] | 30,600 | 7,800 | $94,300 |
| Camanche Dam | 32,800 | 5,000 | $20,740 |
| **Tulare Lake Basin** | | | |
| Isabella Dam[3] | 26,000 | 3,900 | $26,711 |
| Success Dam[3] | 26,600 | 3,200 | $62,616 |
| Terminus Dam[3] | 60,700 | 5,600 | $124,165 |
| Pine Flat Dam[3] | 95,000 | 8,000 | $112,460 |
| **TOTAL 1997 San Joaquin Valley** | | | **$496,250** |

Notes:
1 Damages prevented are in 1997 dollars.
2 Damages prevented updated based on new flow/damage relationships.
3 Damages prevented for these reservoirs include values from the Tulare Lakebed and are not just determined by individual river flows.
4 Multiple index points; individual flows not shown.

## YUBA COUNTY DAMAGE SURVEY FOLLOWING 1997 FLOODS

The eastern levee of the Feather River failed on the evening of January 3, 1997, near the town of Arboga, California. Within 24 hours of the initial failure, the levee breach had reached over 800 feet in length. Floodwaters inundated 12,000 acres, damaging over 700 structures. Although the area was primarily agricultural, many of the damaged structures were concentrated along Country Club Road and in the town of Arboga. In total, approximately 600 residential structures were within the flooded area. This area had a wide range of flooding depths, with maximum depths about 20 feet (structures totally covered) in the south near the levee break to minimal depths in the north near the Yuba County Airport.

### DESCRIPTION OF SURVEY

A residential damage survey was conducted following this flooding in Reclamation District 784 in Yuba County, California. The objective of the study was to develop area-specific data relating depth of flooding to damage costs. The study targeted approximately 200 to 300 residences, such that a representative distribution across all water depth ranges could be obtained. Due to the low number of commercial structures in the area, the survey was limited to residential structures. A detailed description of the survey and a statistical analysis of the results is provided in Appendix A.

The post-flood survey takes a comprehensive look at the damages and nonphysical cost of flooding. Survey data showed a strong relationship between depth and percent damage to structure, percent damage to contents, and days spent in temporary quarters by flood victims. Results from this study can be used to estimate damages to other single story homes in California's Central Valley. Results of this study will be combined with the results of other studies from across the country for estimating nonphysical costs from various flood parameters and estimating the effects of duration, velocity, sediment, and lead-time on flood damage.

The occupants of target residences were interviewed using a questionnaire similar to one used in a survey of Grand Forks, North Dakota, following the April 1997 flooding there. Questions related to damages, costs, and preventive measures taken, as well as an assessment of the approximate value of the property. The survey addressed emergency responses to the flood and costs/damages incurred by the resident. Costs incurred were categorized into three areas: structural damage costs, content damage costs, and nonphysical costs.

Damage survey questionnaires were completed for a total of 260 residences. Of the completed questionnaires, 115 of the residences did not experience water depths within the home (water depth relative to the first floor was less than or equal to zero). The remaining 145 residences experienced measurable water depths within the home relative to the first floor. Depths ranged from several inches to more than 28 feet above the first floor.

### ANALYSIS OF SURVEY RESULTS

The analysis of the Feather River Flood Damage Data Survey can be summarized into four areas: depth-damage analysis, nonphysical flood costs, vehicle damage, and flood emergency response.

The analysis was based on 140 surveys where the survey response was sufficiently complete to analyze and where there was either structural or content damage. A description of the depth-damage analysis follows. Other evaluations are included in Appendix A.

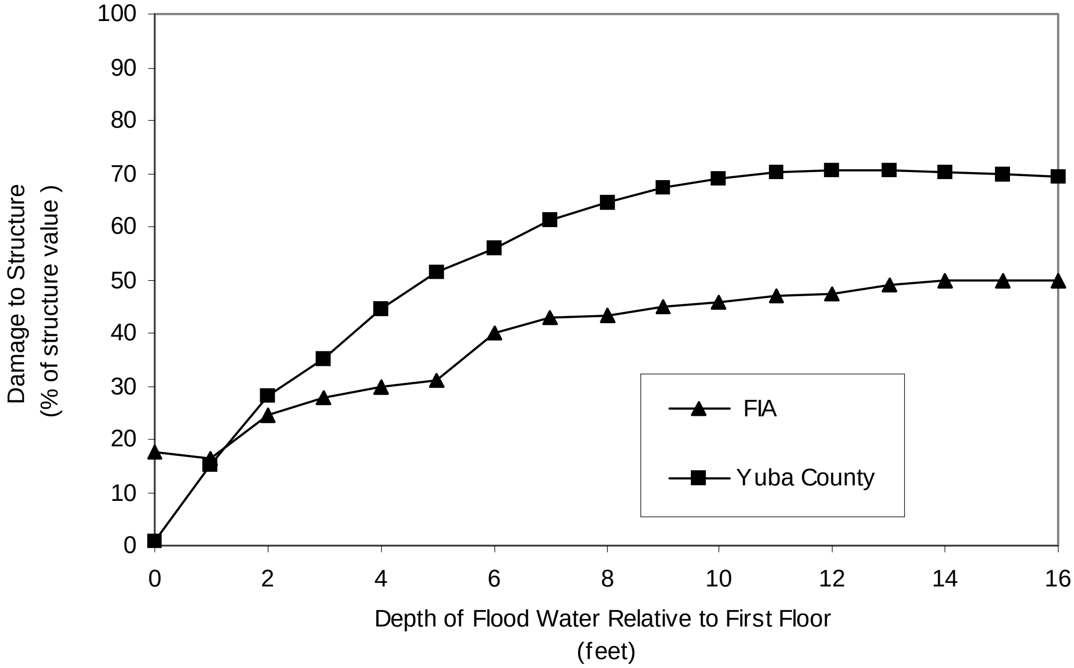
### Depth-Damage Analysis

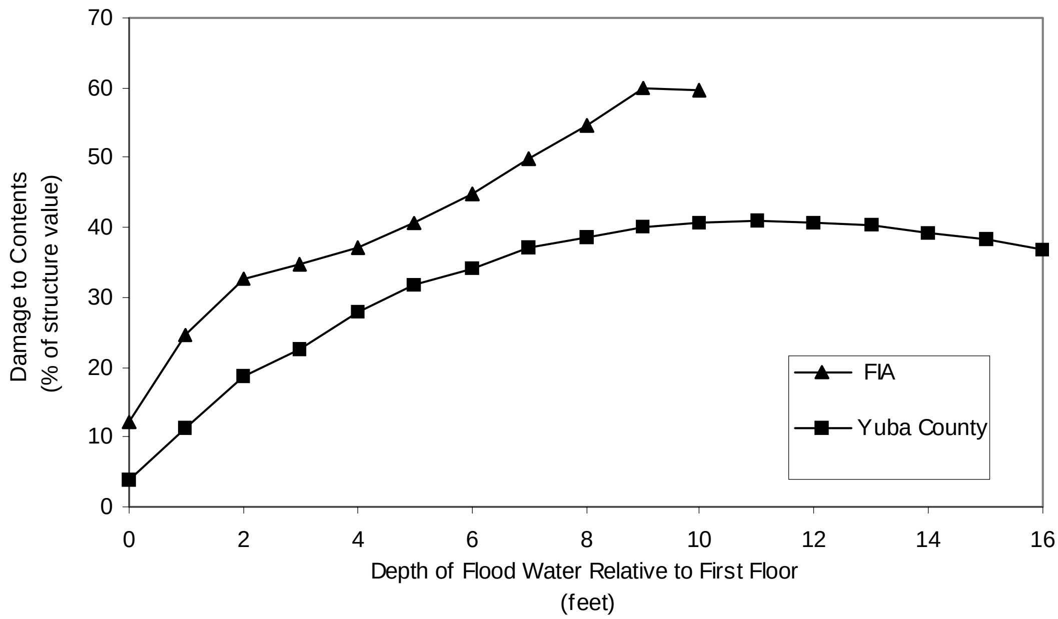
Structure and content depth-damage functions were constructed using regression analysis. Percent damage to a structure was computed by dividing structure damage by structure value for each responding household. Percent damage to contents was constructed by dividing content damage by structure value for each response. Content value for each household was not determined because of the anticipated time and expense and because it was believed that the ratio of content-damage-to-structure-value would be a suitably reliable proxy for the content-damage-to-content-value ratio.

Only the single-story without-basement structure and content models had a sufficient number of cases to produce reliable regression models. There were 111 cases for the structure damage model and 85 cases for the content damage model. Figure A-1 in Appendix A displays the distribution of flood depths reported. The duration of inundation for each structure varied with the location of the structure, but the majority were inundated for around one week. Floodflow velocities were generally slow for all structures, except for the few that were very close to the initial levee break.

The structural damage function for single-story homes with no basement, shown on the next page, begins with very low damage at the first floor level, rises very quickly through the 2-½ to 3-foot level, then flattens out and becomes almost completely flat at about 70 percent damage for the 11 to 20 feet above first floor range. The content damage function, shown on the next page, had a similar slope with damage rising a bit more slowly throughout the lower depths and topping out at more than 9 feet above the first floor level with a ratio of approximately 40 percent content damage to structure value.

The figure below compares both structural and content damage estimates from this survey to national average values reported by FIA. Estimated structural damages in the study area exceed national average damages. This probably reflects the relatively high structural damage to wood and stucco structures prevalent in the study area. National averages are based on damages to single-story residences constructed from a variety of materials, including brick and masonry, which would be expected to sustain lower structural damages than wood and stucco structures at similar flooding depths.


Damage to Structure
(% of structure value )
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
Depth of Flood Water Relative to First Floor
(feet)
FIA
Yuba County


Damage to Contents
(% of structure value)
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
Depth of Flood Water Relative to First Floor
(feet)
FIA
Yuba County