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Sacramento and San Joaquin River Basins

Comprehensive Study

TECHNICAL STUDIES DOCUMENTATION

APPENDIX F

ECONOMICS TECHNICAL DOCUMENTATION

THE RECLAMATION BOARD
PUBLIC SAFETY
WITH FLOOD PROTECTION
STATE OF CALIFORNIA

US Army Corps of Engineers
Sacramento District

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APPENDIX F

ECONOMICS TECHNICAL DOCUMENTATION

INTRODUCTION

In response to extensive flooding and damage experienced in 1997, the United States Congress authorized the U.S. Army Corps of Engineers, Sacramento District (Corps) to undertake a comprehensive analysis of the flood management systems in the Sacramento and San Joaquin river basins and develop plans for reducing flood damages and improving the riverine environment. The Corps and the Reclamation Board of the State of California have conducted the Comprehensive Study to improve flood management and integrate ecosystem restoration in the Sacramento and San Joaquin river basins. The Interim Report 2002 defines a vision, the Comprehensive Plan (guiding principles, approach to developing projects, organizational structure), and an implementation plan for development of future projects in the Sacramento and San Joaquin river basins. Seven regions have been identified based on technical data, stakeholder interest, and non-Federal sponsor input. Potential measures have been identified which could lead to system, regional and local projects.

At this time, studies are being conducted for one potential system-wide and for one potential local project. The potential system-wide project is an Enhanced Flood Response and Emergency Preparedness system for both basins. The potential local project is the Hamilton City Flood Damage Reduction and Ecosystem Restoration Project. A feasibility study is underway for each of these potential projects, which include complete economic analyses.

Purpose of Documentation

The Comprehensive Study's economic analysis is a major undertaking. The floodplains extend over 2.2 million acres, including 1.6 million irrigated crop acres, almost 200,000 structures, and are home to over a half-million people. In addition to economists, several other disciplines contribute to the analysis--hydrologic, hydraulic, and geotechnical engineers and environmental specialists. This appendix (a) introduces the basic Corps' decision criteria and economics guidance, (b) discusses the methods and computer models used in a flood damage reduction analysis, including the application of risk and uncertainty, and (c) presents existing condition (year 2000) flood damage estimates for the Sacramento and San Joaquin river basins. This appendix also describes some preliminary system-wide evaluations that improved the understanding of the complex relationships of both river systems. However, to date no economic analysis has been done for alternative plans, although the information and analyses described in this appendix will serve as the basis for future economic evaluations as projects are identified for more detailed study.

Economic Guidance

The Corps of Engineers economic analysis is based upon the *Principles and Guidelines* (P&G) published in 1983 by the US Water Resources Council and supplemented with Corps Guidance (for example, ER 1105-2-100 "Planning Guidance Notebook" and EM 1110-2-

1619 "Risk-Based Analysis for Flood Damage Reduction Studies"). Because the benefits of potential future projects related to the Comprehensive Study include both flood damage reduction and environmental restoration on a large geographic scale, with implementation expected to occur possibly over decades by Corps, Federal, State, and non-government entities, economic justification for this non-traditional study using traditional Corps methodology raises many challenges. Some of these challenges include the evaluation of projects on a local vs. a system or basin-wide basis; emphasis upon regional and other social impacts; the evaluation of ecosystem benefits; and how to equitably distribute costs among the beneficiaries.

Although both the Corps and the State are working together, the State may ultimately have more flexibility in conducting the economic analysis, and more importantly, making recommendations based on that analysis. For example, the State may place equal weight on all four federal planning accounts (national economic development, environmental quality, regional economic development and other social effects) rather than focusing primarily upon national economic development and environmental quality. Although the Corps is required to perform an "incremental" analysis for individual projects, the State may also evaluate individual projects as part of a larger, regional solution with an overall benefit/cost analysis. Because of these and other differences, the projects recommended by the State (and local agencies) may be different from what would be recommended by a traditional Corps economic analysis.

Study Area

The study area consists of the floodplains of the Sacramento and San Joaquin rivers and the lower reaches of their major tributaries. The Tulare Lake basin is not included in the study area, although the contribution of flood flows from the Kings River to the San Joaquin River is considered. The solution area is the combined watershed of the Sacramento and San Joaquin river basins. These rivers have a combined drainage area of over 43,000 square miles, an area nearly as large as the state of Florida. The study area is shown in Figure 1. Because the focus of the Comprehensive Study is flooding and ecosystem problems related to the Sacramento and San Joaquin rivers, flooding problems along minor tributaries and sub-watersheds to the Sacramento and San Joaquin rivers are not directly included in the Comprehensive Plan.

Within the Sacramento River basin, this problem area includes portions of the following counties: Shasta, Tehama, Butte, Glenn, Colusa, Yuba, Sutter, Solano, Yolo and Sacramento. Some of the larger communities either entirely or partially within the floodplain include (from north to south): Redding, Red Bluff, Hamilton City, Gridley, Colusa, Meridian, Yuba City-Marysville and surrounding communities, Sacramento and surrounding communities, Clarksburg, Walnut Grove, and Isleton.

Within the San Joaquin River basin, the problem area includes part or all of Fresno, Madera, Merced, Stanislaus, and San Joaquin Counties. Some of the larger communities located entirely or partially within the floodplain include (from south to north): Fresno, Mendota, Firebaugh, Dos Palos, Modesto, and the Stockton metropolitan area.

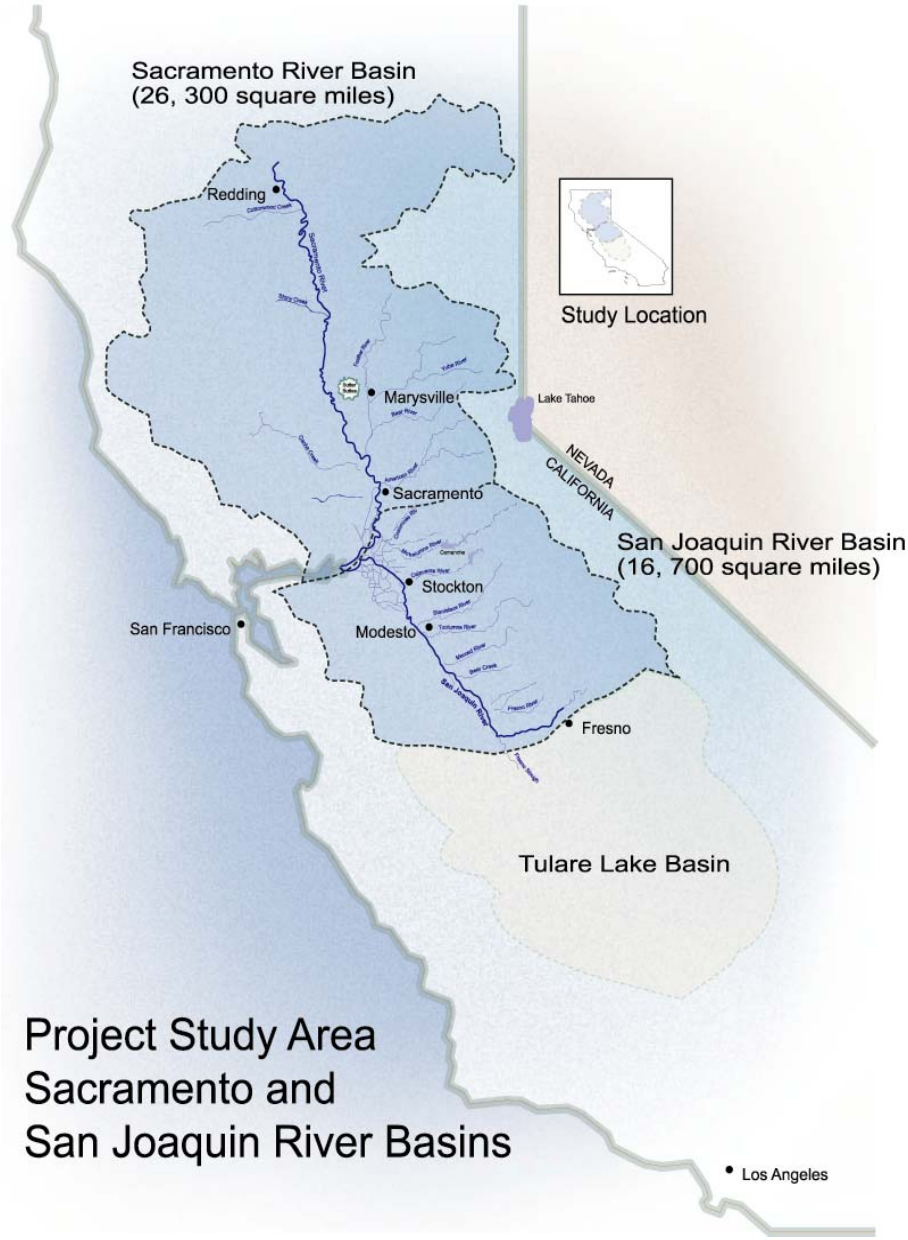


FIGURE 1 – STUDY AREA

FLOOD DAMAGE REDUCTION ANALYSIS METHODS

A primary Corps objective in flood damage reduction studies is to determine the expected annual damage (EAD) along a river reach taking into account all possible flood scenarios and to compare changes in the damage resulting from various alternative plans. Expected annual damage is approximately equivalent to an average annual damage estimate, taking into account all possible storm events that might occur, from very frequent to very infrequent. The determination of EAD in a flood management study must take into account interrelated hydrologic, hydraulic, geotechnical and economic information. Specifically, EAD is

determined by combining the discharge-frequency, stage-discharge (or frequency), and stage-damage functions and integrating the resulting damage-frequency function. Stage refers to water surface elevation. Uncertainties are present for each of these functions and are carried forth into the EAD computation. In addition, for the Comprehensive Study most of the rivers being studied have levees. Adding levees keeps more flow in the channel, allowing less water to break out into adjacent lands. However, as the volume of water behind the levee rises, the probability of levee failure increases. Thus, the derivation of geotechnical levee probability of failure curves becomes very critical to the analysis. Once levees have failed and water enters the floodplain, then stages in the floodplain (which inundate structures and crops) become more critical to the EAD computation than stages in the river channel.

Risk Analysis

Risk involves exposure to a chance of injury or loss. The fact that risk inherently involves chance leads directly to a need to describe and plan for uncertainty. Corps policy has long been to acknowledge risk and uncertainty in anticipating floods and their impacts and to plan accordingly.[1] Historically that planning relied on analysis of the expected long-term performance of flood-damage reduction measures, application of safety factors and freeboard, designing for worse case scenarios, and other indirect solutions (such as engineering judgment) to compensate for uncertainty. These indirect approaches were necessary because of the lack of technical knowledge of the complex interaction of uncertainties in estimating hydrologic, hydraulic, geotechnical, and economic factors due to the complexities of the mathematics required for doing otherwise. However, with advances in statistical hydrology and the availability of computerized analysis tools (such as HEC-FDA described below), it is now possible to improve the evaluation of uncertainties in the hydrologic, hydraulic, geotechnical, and economic functions. Through this risk analysis, and with careful communication of the results, the public can be better informed about what to expect from flood-damage reduction projects and thus can make more informed decisions.

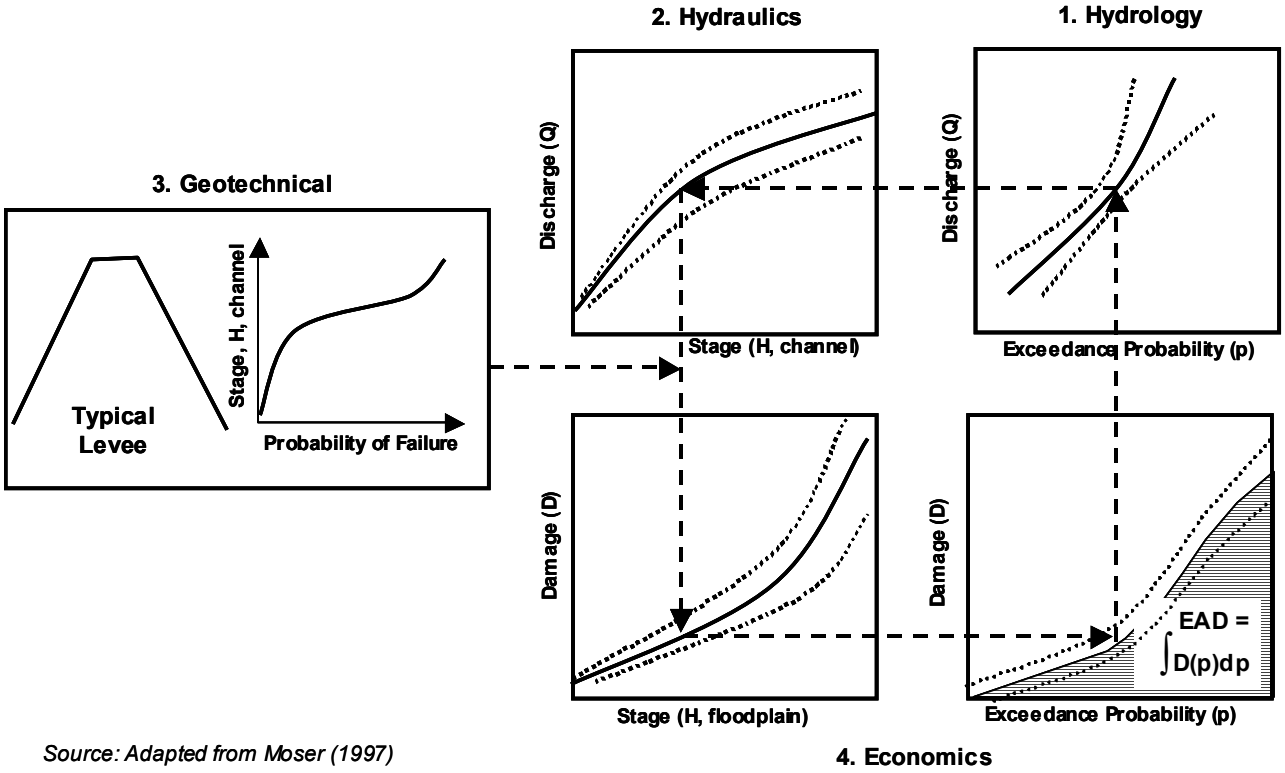
The determination of EAD for a flood reduction study must take into account complex and uncertain hydrologic, hydraulic, geotechnical, and economic information:

- **Hydrologic -** The discharge-frequency function describes the probability of floods equal to or greater than some discharge Q,
- **Hydraulics -** The stage-discharge function describes how high (stage) the flow of water in a river channel might be for given volumes of flow discharge,
- **Geotechnical -** The geotechnical levee failure function describes the levee failure probabilities vs. stages in channel with resultant stages in the floodplain, and
- **Economics -** The stage-damage function describes the amount of damage that might occur given certain floodplain stages.

Figure 2 illustrates the conceptual risk approach for Corps' flood damage analyses. To find the damage for any given flood frequency, the discharge for that frequency is first located in the discharge-frequency panel (panel #1), then the river channel stage associated with that discharge value is determined in the stage-discharge panel (panel #2). As stated above, most

1 In a flood damage reduction study, risk is defined is the probability of failure during a flood event. Uncertainty is the measure of the imprecision of knowledge of variables in a project plan.

of the rivers being studied have either project or non-project levees which typically fail before the water reaches the top (panel #3).[2] Once levees have failed and water enters the floodplain, then stages (water depths) in the floodplain inundate structures and crops and cause damage (panel #4, left side).[3] By plotting this damage and repeating for process many times, the damage-frequency curve is determined (panel #4, right side).[4] EAD is then computed by finding the area under the flood damage-frequency curve by integration for both without and with project conditions. Reductions in EAD attributable to projects are flood reduction benefits.



Source: Adapted from Moser (1997)

FIGURE 2 - CONCEPTUAL RISK APPROACH FOR ESTIMATING FLOOD DAMAGE

Uncertainties are present for each of the functions discussed above and these are carried forth from one panel to the next, ultimately accumulating in the EAD. These uncertainties are shown in Figure 2 as "error bands" located above and below the hydrologic, hydraulic and economics curves.[5]

2 Project levees are levees that are part of a Federal flood control project. They include levees built by the corps as well as levees built by others and brought up to the corps design standards applicable at the time of incorporation into the federal project. The maintenance of project levees is usually the responsibility of the local sponsors. Non-project levees are not part of a federal flood control project and are built and maintained by individuals and agencies other than the Corps.

3 For reaches with no levees, the stage in the channel and overbank areas is used to determine damage.

4 The HEC-FDA model uses Monte Carlo analysis to repeat this "sampling" process thousands of times. Mathematically, HEC-FDA computes EAD in a different manner than illustrated by this figure.

5 Uncertainty in the geotechnical levee probability of failure curves are multitude in character and the resultant curve used in the analysis reflects how well that levee can be expected to perform during random periods of

Some of the important uncertainties specific to the Comprehensive Study include:

- **Hydrologic -** Uncertainty factors include hydrologic data record lengths that are often short or do not exist, precipitation-runoff computational methods that are not precisely known, and imprecise knowledge of the effectiveness of flow regulation.[6]
- **Hydraulics -** Uncertainty arising from the use of simplified models to describe complex hydraulic phenomena, including the lack of detailed geometric data, misalignments of hydraulic structures, material variability, and from errors in estimating slope and roughness factors.
- **Geotechnical -** Uncertainty in the geotechnical performance of flood control structures during loading from random events such as flood flows and earthquakes affect levee performance. Other uncertainties may include geotechnical parameters such as soil and permeability values used in analysis, mathematical simplifications in the analysis models, frequency and magnitude of physical changes or failure events, and the uncertainty of unseen features such as rodent burrows, cracks within the levee, or other defects.
- **Economics -** Uncertainty concerning land uses, depth/damage relationships, structure/content values, structure locations, first floor elevations, floodwater velocity, the amount of debris and mud, flood duration, and warning time and response of floodplain inhabitants.

Appendix E – Risk Analysis provides a more detailed description of the Corps' risk analysis.

Flood Damage Reduction Analysis Models

To perform the flood damage analysis for the Comprehensive Study, the following economic models are being used:

HEC-FDA

The Corps primary model for performing flood damage reduction analysis is the Hydrologic Engineering Center's Flood Damage Reduction Analysis model (HEC-FDA, V1.2), which integrates hydrologic, hydraulic and geotechnical engineering and economic data. HEC-FDA incorporates uncertainty for risk analysis using a Monte-Carlo simulation procedure. Plans can include structural as well as non-structural components. Although HEC-FDA was designed to estimate urban flood damage, it was adapted for agricultural analyses for the Comprehensive Study. The primary outputs of HEC-FDA that are used in project formulation and evaluation are project performance statistics and expected annual damage. Project performance statistics include the *expected annual probability of flooding* from all events in any given year, the *long-term risk of flooding* over a 10-, 25-, and 50-year period, and the *conditional non-exceedance probability for specific events* (i.e., the probability of

high flows for a particular reach length. Typically, the greater the length of the levee reach, the less reliable that reach will perform during a flood event.

6 The hydrologic data record lengths (period of record) are the number of years of a systematic record of peak discharges at a stream gage. This parameter directly influences the uncertainty associated with the frequency-discharge function shown in Figure 2 and consequently the project performance statistics discussed later in this report. In general, a longer period of record implies less uncertainty associated with this function. For the Comprehensive Study, the hydrologic periods of record were identified for each impact area.

passing specific flood events). In a risk-based analysis, expected annual damage is defined as the average or mean of all possible values of damage determined by Monte Carlo sampling of discharge-exceedance probability, stage-discharge, and stage-damage relationships and their associated uncertainties (Figure 2). It is calculated as the integral of the damage-probability function.

@RISK

Although HEC-FDA can be used to generate stage-damage curves by inputting structural inventories directly into it, a decision was made between Sacramento District and HEC staff not to use this option but instead generate these curves outside of HEC-FDA using @RISK. The completed curves are then input into HEC-FDA. The primary reason for this decision was the presence of overland flooding in many of the impact areas. In other words, flooding in many of the impact areas originates in other impact areas. A good example of this is in the Colusa basin along the western portion of the Sacramento Valley. Water can breakout along the right (west) bank of the Sacramento River along the northern portions of SAC 7 (Colusa Basin North), then flow south 40 or 50 miles. As it flows south, it can influence flooding in the SAC 8 (Colusa) and SAC 9 (Colusa Basin South) impact areas. Thus, flood damage in SAC 8 and SAC 9 cannot be reliably linked to river stages within or adjacent to those impact area, which HEC-FDA attempts to do. Instead, flood damage was directly linked to flood depths at the parcels (regardless of the source of flooding), using GIS and other methods. @RISK was used to develop the stage-damage curves using the parcel and depth information developed by GIS.

Key economic uncertainty assumptions, which are input into the @RISK model, include:

Structure Value - Errors are likely to occur in estimating the depreciated replacement values of structures. Based upon past Corps studies, the coefficient of variation used in @RISK for all damage categories is 15% (standard deviation equals 15% of the mean value). The probability distribution is assumed normal.

Content Value - Errors are likely to occur in estimating content values. Based upon past Corps studies, the coefficient of variation used in @RISK for all damage categories is 15% (standard deviation equals 15% of the mean value). The probability distribution is assumed normal.

Foundation Height - Errors are likely to occur in estimating the foundation heights of buildings. Because of limited foundation height data for the large areas included within the Comprehensive Study, a triangular distribution is initially being used for all damage categories (except mobile homes and crops) with the distribution defined by a minimum, maximum and most likely foundation height. For example, based on data from other studies, it was determined that the foundation heights of single-family residences would occur somewhere between 0.5 feet and 3 feet, with a most likely value of 1.14 feet. In addition, a 0.6 standard error was used in @RISK to account for potential measurement errors associated with these triangular distributions.

Number of Stories - To account for errors in estimating the number of stories of structures, a discrete probability distribution was used for the above damage categories (except mobile homes and industrial) with the ratio of one-story to two story structures determined by reviewing available assessor parcel data. For example, based upon other studies it was

determined that there would be an 85% chance of a single-family structure being 1 story and a 15% chance of it being two or more stories.

Depth-damage Curves - Errors are likely to be present in post-flood surveys used to determine structural and content depth-damage relationships. Corps' depth-damage curves include standard deviations, and for the Comprehensive Study we used the highest standard deviations at any specific depth. For example, a 5% coefficient of variation was used in @RISK for the single-family, multi-family, and farmsteads damage categories. A coefficient of variation value of 10% was used for the other damage categories.

Spreadsheet Analysis (Upper Sacramento Reach)

For the Upper Sacramento reach, a different methodology was used to estimate flood damage. The CA DWR performed the hydraulics studies for this reach using HEC RAS rather than UNET; thus, stage-frequency curves required by HEC-FDA were not generated. Another approach would have been to input the water surface elevations into HEC-FDA; however, only three water surface elevations were generated (for the 50-, 100- and 200-year events) rather than eight water surface profiles required by HEC-FDA. Thus, estimated expected annual damage was based upon the depths for these three events at the individual parcels and the computations were performed using spreadsheets rather than within HEC-FDA. Therefore, project performance statistics are not available for this reach. While this approach is not completely satisfactory, if any projects are eventually recommended for this reach, more detailed hydraulic and economic analyses can be performed at that time.

GIS

Although not an economics program, the use of Geographic Information Systems software (Arc View) allowed the relatively fast identification of thousands of structures within the floodplains where digitized parcel maps were available. Where possible, the corresponding data required for flood damage analysis (frequencies and depths of events at specific parcels, improvement values, etc.) was also developed using GIS.

In addition to these models, critical input into HEC-FDA comes from hydraulic models (UNET; river channel stage-frequencies) and FLO-2D (floodplain delineations).

Floodplains

One of the most important steps in a flood damage analysis is the identification of areas subject to flooding (floodplains). Unfortunately, there can be confusion when comparing floodplain maps prepared by the Comprehensive study and those prepared by other agencies, particularly the Federal Emergency Management Agency. Although FEMA floodplain maps prepared for the National Flood Insurance Program and the inundation areas prepared for the Comprehensive Plan have the same fundamental objective -- to show the extent of flood risk within communities relying upon hydrologic and hydraulic analyses -- in fact they are significantly different. First, flood insurance rate maps (FIRMs) prepared by FEMA are used for flood insurance and floodplain management regulatory purposes. The intended use of the Comprehensive Plan maps is to evaluate the performance of the current and modified flood management systems under a range of hydrologic conditions. As such, Comprehensive Study inundation maps should only be used at the system-wide scale because they lack local

detail.[7] In contrast, FEMA uses regional floodplains plus local flooding so FEMA maps can be used at the site-specific scale.

In addition, for the Comprehensive Plan floodplains, a hydraulic analysis was developed to capture more accurately the levee breach probability. A likely failure point (LFP) profile was developed to represent the elevation at which there is a 50% probability of levee failure. The LFP was developed from a regional assessment of levee conditions, past investigations, and engineering judgment. This probability of failure approach is different than the methodology used for FEMA maps which assume flooding occurs at a particular water surface elevation with respect to top of levee, more commonly referred to as freeboard, which is only in part due to levee stability.

Because the Comprehensive Study focuses on the performance of the flood management system as a whole, as levee failures cause flood flows to be removed from the channels, the amount of water in downstream reaches is decreased. FEMA floodplains consider each levee break separately. The levee breaks cause flood flows to be removed from the channel but do not cause the river stage to be lowered downstream. Essentially, the flood flows in the channel are unchanged by upstream levee breaks, so higher flows are conveyed to downstream reaches.

Although the Comprehensive Study's hydraulic analysis modeled floods with a 2-, 10- 25-, 50-, 100-, 200-, and 500-year return frequencies; the economic analysis did not utilize the 2- or 25- year data. *Appendix D - Hydraulic Technical Documentation* describes the models, methods, and assumptions (including the important levee breach methodology) utilized in the development of the floodplains.

In addition to the Sacramento and San Joaquin River basin floodplains described below, the Department of Water Resources has recently prepared floodplains of the Upper Sacramento River, from Vina (east of Corning) to Keswick Dam, just downstream of Shasta Dam. These floodplains are for the in 50-, 100- and 200-year event floodplains. The 1 in 200 year floodplain encompasses about 47,000 acres. Because these floodplains are further upstream and the river is more incised, the floodplains tend to be much narrower than further south. Six impact areas have been identified and the land use and structural inventories were developed. Although mostly rural, these floodplains do cut through the communities of Redding and Red Bluff and totally include the community of Tehama.

EXISTING SOCIOECONOMIC CONDITIONS

The Central Valley has been one of the state's fastest growing areas during the last few decades. Table 2 shows population growth trends for the counties located in the Sacramento and San Joaquin river basins compared to the entire state. In Sacramento River basin counties, population growth for the 2000 through 2020 period is projected to be about 41%, compared to about 50% for San Joaquin River basin counties. Both of these percentage increases are greater than the statewide average of 33% for the same period. There are numerous reasons for the increased population growth within the Central Valley. One of the most important is the greater availability of open and affordable land compared to the more

[7] As noted earlier, the Comprehensive Study has focused upon the floodplains of the Sacramento and San Joaquin rivers (main stems) and the lower reaches of their major tributaries.

urbanized areas along California's coast (for example, the Los Angeles and San Francisco metropolitan areas).

Economically, the Central Valley differs substantially compared to the rest of the state. Agriculture is the main industry within the valley, with over 350 different crops being grown (some exclusively in California). Agriculture within the valley supplies products not only to the state and nation, but around the world as well. Thousands of farming and food processing and packaging jobs will continue to be a significant part of the Central Valley's economy into the near future. The proportion of manufacturing's share of total wage and salary jobs in the Central Valley is less than elsewhere in the state, reflecting the historical concentration of manufacturing in the coastal areas. However, there has been increased manufacturing in the electronics and computer industries as companies relocate from the higher-cost San Francisco Bay Area. As with other areas in the state, the growth in services and construction sectors has been high in the Central Valley because of increasing urbanization. The government sector is considerably greater in the Central Valley than for the entire state, reflecting not only the state capital in Sacramento but also several large defense-related, educational, and other facilities. Two major highways traverse the Central Valley from north to south (Interstate 5 located along the western side of the valley and State

TABLE 2
COUNTY POPULATION PROJECTIONS

Basin / County	July 1990	July 2000	July 2005	July 2010	July 2015	July 2020	2000–2020 Growth
Sacramento							
Shasta	145,300	165,000	185,700	203,500	217,500	231,000	40.0%
Tehama	51,000	56,700	63,400	71,500	78,200	85,100	50.1%
Butte	187,900	205,400	235,000	259,800	281,200	308,900	50.4%
Glenn	25,700	26,900	31,800	36,700	41,300	46,500	72.9%
Colusa	17,000	19,100	24,200	29,200	33,900	39,200	105.2%
Yuba	60,400	60,800	66,000	71,400	76,300	81,900	34.7%
Sutter	66,500	80,200	90,400	99,600	107,200	115,600	44.1%
Solano	350,500	400,300	444,100	485,500	521,200	559,500	39.8%
Yolo	146,000	170,900	188,600	205,000	219,500	236,400	38.3%
Sacramento	1,070,500	1,242,000	1,368,500	1,486,500	1,591,100	1,707,600	37.5%
Subtotal	*2,120,800*	*2,427,300*	*2,697,700*	*2,948,700*	*3,167,400*	*3,411,700*	*40.6%*
San Joaquin							
San Joaquin	496,300	573,600	645,600	727,800	803,400	887,600	54.7%
Stanislaus	383,800	454,600	522,700	587,600	646,800	712,100	56.6%
Merced	186,300	214,400	239,900	266,700	292,400	322,700	50.5%
Madera	91,600	127,700	152,600	178,900	203,000	229,200	79.5%
Fresno	684,500	816,400	893,300	970,900	1,043,100	1,134,600	39.0%
Subtotal	*1,842,500*	*2,186,700*	*2,454,100*	*2,731,900*	*2,988,700*	*3,286,200*	*50.3%*
Total	**30,652,000**	**34,480,300**	**37,473,500**	**40,262,400**	**42,711,200**	**45,821,900**	**32.9%**

Source: CA. Department of Finance, Population Research Unit, Interim Population Projections, June 2001

Highway 99 located along the eastern side) and one from west-to-east (Interstate 80 which goes through Sacramento). Major regional passenger airports include Fresno Air Terminal, Stockton Air Terminal, and Sacramento International Airport. Major railroad lines cross the Central Valley from north-to-south and east-to-west.

HISTORICAL FLOOD DAMAGE

Due to its climate and geography, flooding is a frequent and natural event in the Central Valley. Historically, the Sacramento River basin has been subject to floods that result from winter and spring rainfall as well as rainfall combined with snowmelt. The San Joaquin River basin has been subject to floods that result from both rainfall that occurs during the late fall and winter months, and unseasonable and rapid melting of the winter snow pack during the spring and early summer months. Major floods in the Central Valley within the last 20 years (1983, 1986, 1995, and 1997) have caused significant damage, as shown in Table 3. With the exception of 1986, combined annual flood damage for both basins was about one-half billion dollars.

TABLE 3
CENTRAL VALLEY HISTORICAL FLOOD DAMAGE

Event (Year)	Damages in $Millions[1]		
	Sacramento River Basin	San Joaquin River Basin	Total
1983 [2]	$91	$324	$415
1986 (February)	$172	$15	$187
1995 [3]	$305	$193	$498
1997 (January)	$301	$223	$524

1. Values represent conditions and price levels for the year of the event.
2. No one single storm caused the flood damages in 1983. Normal precipitation averaged 190 percent of normal.
3. January and March.
Source: USACE, Sacramento District, Post - Flood Assessment, March 1999.

It should be noted that these estimates should not be directly compared to the existing condition expected annual damage estimated in this study. First, the damage estimates in Table 3 include damage occurring along the main stems of the Sacramento and San Joaquin rivers as well as their tributaries, whereas the expected annual damage estimates developed in this study are just for the areas along the main stems and lower portions of the tributaries. Second, the San Joaquin River basin damage estimates also include the Tulare Lake basin, which is excluded from this study. Third, the damage estimates presented in Table 3 are for specific events (sometimes multiple events in one year), whereas this study's expected annual damage estimates take into account all possible flood events, from those that are relatively small (for example, 1 in 10 year return frequency event) to the very large (for example, the 1 in 500 return frequency event). Thus, although the estimates in Table 3 provide useful background information concerning flood damage in these basins, they are not directly comparable to the expected annual damage estimates discussed below.

EXISTING CONDITION FLOOD DAMAGE

Impact Areas

Because the large Comprehensive Study floodplains (approximately 2.2 million acres, or about 3,400 square miles) are not homogenous but instead contain areas subject to different types of flooding (for example, the "overland" flooding characteristic of the Colusa basin or the "bathtub" flooding of islands in the Delta), impact areas were delineated within the floodplains to facilitate the flood damage analysis. These impact areas were identified based primarily upon flooding characteristics (sources and flow patterns), underlying land uses and the location of potential measures. The outermost extent of the impact areas is based upon the delineation of the 1 in 500 year floodplains. Within the Sacramento River basin, 62 impact areas were identified covering about 1.5 million acres. Six additional impact areas were identified in the Upper Sacramento reach (about 47,000 acres). In the smaller San Joaquin River basin (about 654,000 acres), 42 impact areas were identified. Tables 4 and 5 list the impact areas and their sizes, and Figures 3 and 4 show their location. The Comprehensive Study has identified almost 198,000 parcels (with an estimated population of over 600,000) currently within the 1 in 500 year floodplain for both basins. Key physical and socioeconomic characteristics of the impact areas are shown in Table 6.

Damage Categories

The damage analysis focuses upon different land uses. Damage categories used in the Comprehensive Study economic analysis include:

- **Residential** - Single and multi-multi-family structures;
- **Mobile homes -** Mobile or manufactured housing units;
- **Commercial -** Offices, retail facilities, hotels and motels;
- **Industrial -** Manufacturing plants, oil refineries, meat packing plants, and canneries, etc.;
- **Public/semi-public -** Institutions (hospitals, prisons, etc.), municipal buildings, theaters, churches, schools, etc.;
- **Farmsteads -** Residential structures with barns and sheds found on farms. Items not included are irrigated crops (which are included in the crop damage category) and other farmstead items, such as irrigation equipment;
- **Crops -** Field crops (corn, beans, wheat, cotton, safflower), fruit and nut crops (almonds, walnuts, peaches, pears, prunes), alfalfa, mixed pasture, rice, truck crops (melons, tomatoes) and vine crops; and
- **Other** - Damage to autos and roads, traffic disruption, and emergency response costs. These have only been estimated for a few of the urbanized impact areas within the Sacramento River basin.

TABLE 4
SACRAMENTO RIVER BASIN IMPACT AREAS

Impact Area No.	Impact Area Name	Acres	Impact Area No.	Impact Area Name	Acres
Upper Sacramento					
US 1	Redding	3,358	US 4	Los Molinos	28,162
US 2	Anderson	3,374	US 5	Red Bluff	2,243
US 3	Bend	9,503	US 6	Tehama	132
				Subtotal	*46,774*
Sacramento					
SAC 1	Woodson Bridge East	28,873	SAC 32	Rec Dist 70-1660	66,658
SAC 2	Woodson Bridge West	6,423	SAC 33	Meridian	235
SAC 3	Hamilton City	434	SAC 34	Rec Dist 1500 East	66,351
SAC 4	Capay	9,645	SAC 35	Elkhorn	13,287
SAC 5	Butte Basin	182,862	SAC 36	Natomas	73,109
SAC 6	Butte City	50	SAC 37	Rio Linda	10,457
SAC 7	Colusa Basin North	87,530	SAC 38	West Sacramento	6,086
SAC 8	Colusa	4,318	SAC 39	Rec Dist 900	6,861
SAC 9	Colusa Basin South	130,730	SAC 40	Sacramento	66,701
SAC 10	Grimes	73	SAC 41	Rec Dist 302	5,784
SAC 11	Rec Dist 1500 West	65,401	SAC 42	Rec Dist 999	29,913
SAC 12	Sycamore Slough	7,905	SAC 43	Clarksburg	446
SAC 13	Knight's Landing	745	SAC 44	Stone Lake	24,027
SAC 14	Ridge Cut (North)	3,338	SAC 45	Hood	193
SAC 15	Ridge Cut (South)	7,962	SAC 46	Merritt Island	4,475
SAC 16	Rec Dist 2035	13,069	SAC 47	Rec Dist 551	9,136
SAC 17	East of Davis	9,000	SAC 48	Courtland	346
SAC 18	Honcut	29,667	SAC 49	Sutter Island	2,492
SAC 19	Sutter Buttes North	38,873	SAC 50	Grand Island	16,161
SAC 20	Gridley	1,120	SAC 51	Locke	692
SAC 21	Sutter Buttes East	63,675	SAC 52	Walnut Grove	482
SAC 22	Live Oak	2,030	SAC 53	Tyler Island	8,736
SAC 23	District 10	12,274	SAC 54	Andrus Island	14,829
SAC 24	Levee Dist. #1	148,893	SAC 55	Ryer Island	11,979
SAC 25	Yuba City	24,392	SAC 56	Prospect Island	1,618
SAC 26	Marysville	1,425	SAC 57	Twitchell Island	3,842
SAC 27	Linda-Olivehurst	15,819	SAC 58	Sherman Island	10,226
SAC 28	Rec Dist 384	12,582	SAC 59	Moore	11,952
SAC 29	Best Slough	12,265	SAC 60	Cache Slough	15,847
SAC 30	Rec Dist 1001	72,679	SAC 61	Hastings	4,591
SAC 31	Sutter Buttes South	11,159	SAC 62	Lindsey Slough	7,493
				Subtotal	*1,500,226*
				TOTAL ACRES	**1,547,000**

TABLE 5
SAN JOAQUIN RIVER BASIN IMPACT AREAS

Impact Area No.	Impact Area Name	Acres
SJ 1	Fresno	9,922
SJ 2	Fresno Slough East	43,928
SJ 3	Fresno Slough West	7,236
SJ 4	Mendota	1,506
SJ 5	Chowchilla Bypass	48,982
SJ 6	Lone Willow Slough	74,608
SJ 7	Mendota North	3,050
SJ 8	Firebaugh	668
SJ 9	Salt Slough	142,265
SJ 10	Dos Palos	2,169
SJ 11	Fresno River	5,282
SJ 12	Berenda Slough	33,194
SJ 13	Ash Slough	16,784
SJ 14	Sandy Mush	11,755
SJ 15	Turner Island	15,310
SJ 16	Bear Creek	16,626
SJ 17	Deep Slough	2,074
SJ 18	West Bear Creek	28,075
SJ 19	Fremont Ford	8,008
SJ 20	Merced River	7,308
SJ 21	Merced River North	23,659
SJ 22	Orestimba	4,703
SJ 23	Tuolumne South	7,198
SJ 24	Tuolumne River	4,864
SJ 25	Modesto	3,555
SJ 26	3 Amigos	3,649
SJ 27	Stanislaus South	9,517
SJ 28	Stanislaus North	17,390
SJ 29	Banta Carbona	5,149
SJ 30	Paradise Cut	7,751
SJ 31	Stewart Tract	4,898
SJ 32	East Lathrop	1,546
SJ 33	Lathrop/ Sharpe	3,025
SJ 34	French Camp	12,163
SJ 35	Moss Tract	2,059
SJ 36	Roberts Island	18,187
SJ 37	Rough and Ready Island	1,360
SJ 38	Drexler Tract	5,516
SJ 39	Union Island	23,865
SJ 40	Southeast Union Island	1,218
SJ 41	Fabian Tract	6,556
SJ 42	RD 1007	7,611
	TOTAL ACRES	**654,189**

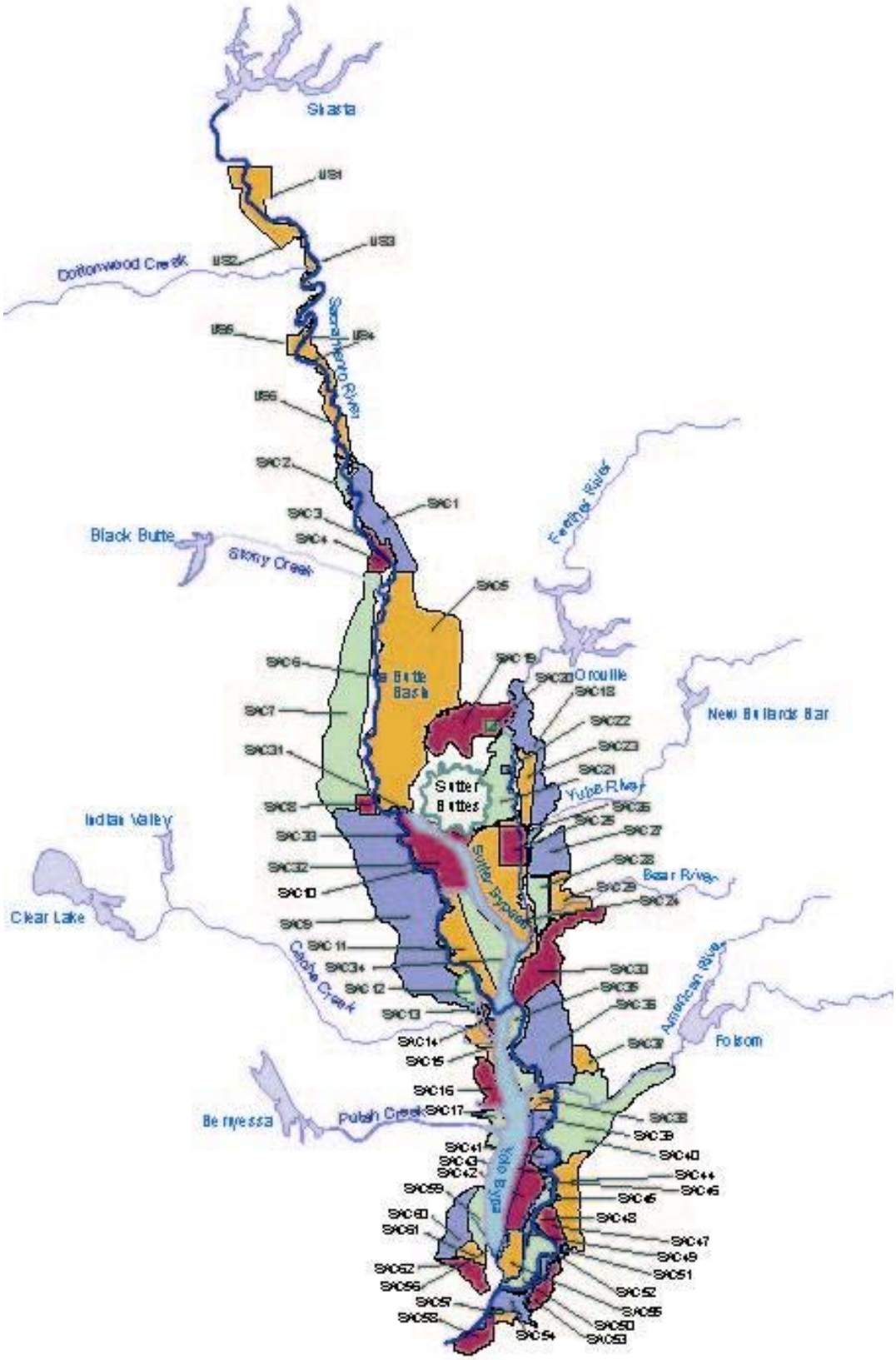

Shasta
Cottonwood Creek
Sacramento River
Black Butte
Stony Creek
Feather River
Butte Basin
Oroville
New Bullards Bar
Sutter Buttes
Yuba River
Indian Valley
Sutter Bypass
Bear River
Clear Lake
Cache Creek
American River
Folsom
Berryessa
Putah Creek
Yolo Bypass

FIGURE 3 - SACRAMENTO RIVER BASIN IMPACT AREAS

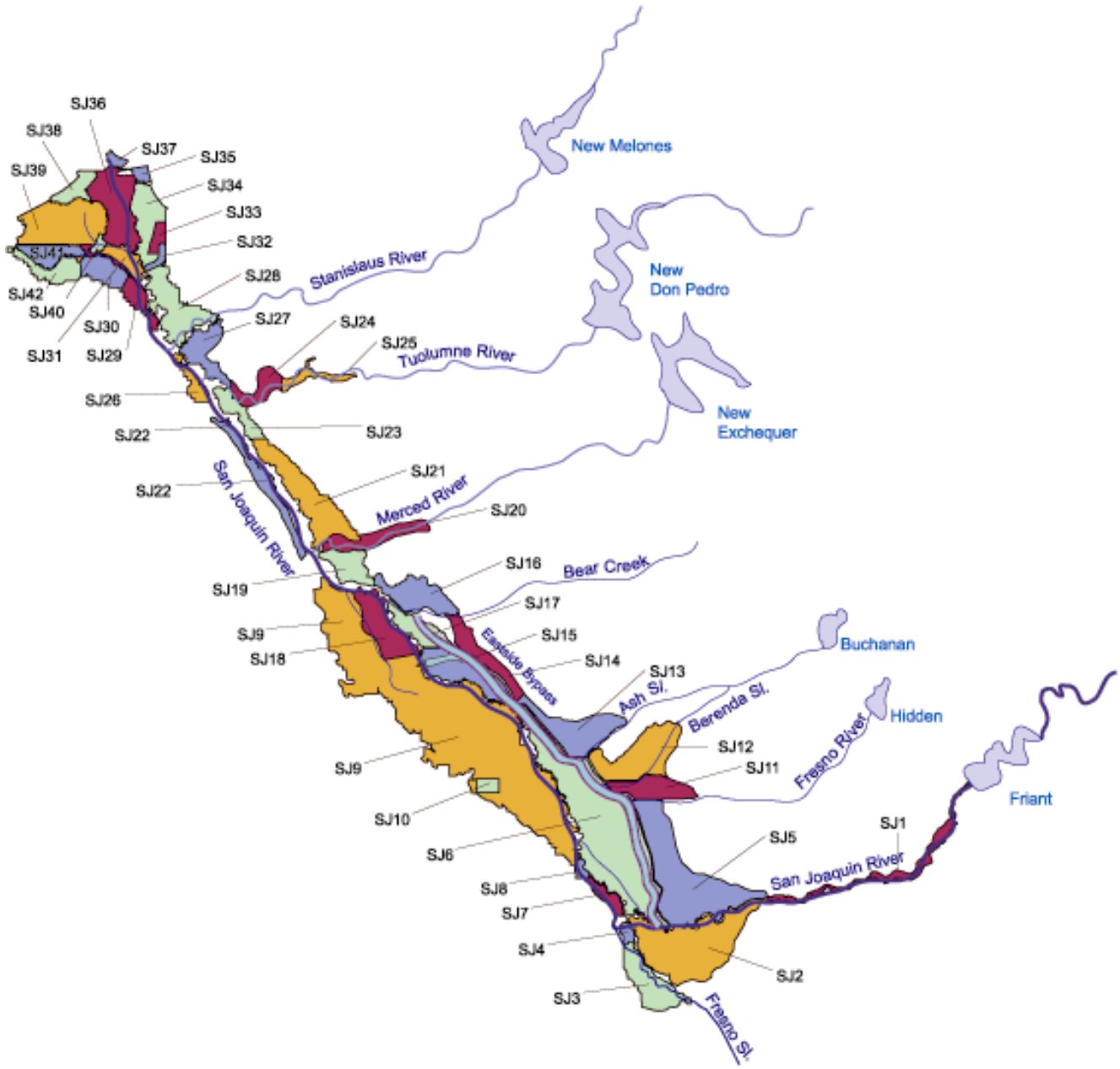


FIGURE 4 - SAN JOAQUIN RIVER BASIN IMPACT AREAS

TABLE 6
KEY CHARACTERISTICS OF IMPACT AREAS

River Basin	Size of Floodplains (Acres)[1]	No. of Impact Areas	Population at Risk	Parcels [2]		Crops	
				Number	Structure/ Contents Value ($Billions)	Acres	Annual Production Value ($Billions)
Sacramento	1,547,000	68	570,100	184,500	$44.0	1,114,400	$1.3
San Joaquin	654,000	42	42,700	13,400	$2.9	436,900	$0.5
Total	*2,201,000*	*110*	*612,800*	*197,900*	*$46.9*	*1,551,300*	*$1.8*

1. 1 in 500 risk floodplains. Includes Upper Sacramento reach (Vina to Keswick, 1 in 200 risk floodplain).
2. Residential, commercial, industrial, and public service land uses. Residential includes single/multiple family housing units, mobile homes, and farmsteads.

Land Use/Structural Inventories

GIS was used to develop crop and other land use inventories for both basins utilizing California Department of Water Resource's digitized land use files. GIS was also used to develop floodplain structural inventories using digitized county parcel map files for the San Joaquin River basin. Unfortunately, digitized parcel maps were not available for most counties within the Sacramento River basin. An attempt was made to identify parcels through computerized geocoding of street addresses, but this was not completely satisfactory since not all parcels had street addresses, especially in rural areas. Parcels not identified by digitized parcel maps or geocoding of street addresses were identified by physically comparing floodplain maps with county assessor parcel maps. Structural inventories developed for the Corps' American River investigation were also utilized. Parcels identified within floodplains can be linked to recent computerized assessor data files to obtain information such as land use, improvement values, sizes, etc. In addition, these parcels could be linked with computerized floodplain files to identify flood depths each flood event. Tables 7 and 8 summarize the number of parcels and their estimated structural and contents values, discussed below.

TABLE 7
NUMBER OF PARCELS

Floodplain	Sacramento[1]	San Joaquin	Total
Residential[2]	169,234	10,284	179,518
Mobile Homes	1,493	218	1,711
Commercial	7,441	587	8,028
Industrial	1,212	158	1,370
Public	2,189	128	2,317
Farmsteads	3,336	1,976	5,312
Total	**184,905**	**13,351**	**198,256**

Notes:
1. *Within 1 in 500 risk floodplain, except in the Upper Sacramento Region (1 in 200 risk floodplain only).*
2. *Includes single and multi-family parcels.*

TABLE 8
STRUCTURAL AND CONTENT VALUES
(In $ Millions, 2001)

Floodplain	Sacramento[1]	San Joaquin	Total
Residential[2]	$23,759	$1,080	$24,839
Mobile Homes	$129	$16	$145
Commercial	$12,881	$363	$13,244
Industrial	$2,862	$1,167	$4,029
Public	$4,007	$50	$4,058
Farmsteads	$379	$242	$621
Total	$44,018	$2,919	$46,937

Notes:
1. *Within 1 in 500 risk floodplain, except in the Upper Sacramento Region (1 in 200 risk floodplain only).*
2. *Includes single and multi-family parcels.*

Structural Value

Once parcels (and their associated assessor parcel numbers) were identified, they were linked to the assessor data files to obtain structural improvement values and other information. However, the assessed structural improvement values listed in the assessor parcel database do not fully reflect depreciated replacement values needed for flood damage analyses. Under California's Proposition 13, improvement values may increase at a maximum rate of only 2% per year from the date a property is sold. Thus, adjustments were made to the assessed values by comparing them with update factors provided by Marshall & Swift, an authoritative residential and commercial appraisal guide. These factors take into account market changes in property values rather than legislatively imposed changes. Values were updated to October 2001 prices.

Publicly owned parcels (such as schools) do not contain improvement values because these parcels are not assessed property taxes. Thus, they are not currently included in the structural inventories. Work is underway to assign improvement values to these parcels by applying Marshall & Swift construction factors ($/sq ft).

Contents Values

Contents values were assigned based upon percentages developed by past Corps of Engineers studies. These percentages are: residential and mobile homes, 50%; commercial, 100%, industrial, 150%, public/semi-public, 50%; and farmsteads, 65%. These percentages are applied to structural values, thus a $100,000 house would have contents assumed to be valued at $50,000.

Urban Depth-Damage Relationships

Damage generally increases as depth of flooding increases. Generic residential depth-damage functions developed by the Corps' Institute for Water Resources are being used in the Comprehensive Study. Table 9 presents the IWR structural and contents depth-damage curves for residential one-story structures with no basements. For the other urban damage categories, depth-damage functions developed by the Sacramento District (based upon FEMA information) are being used.

TABLE 9
IWR STRUCTURAL AND CONTENTS DEPTH-DAMAGE FUNCTIONS
(ONE STORY RESIDENCE WITH NO BASEMENT)

Depth (feet)	Structural Depth-Damage		Content Depth-Damage[1]	
	Mean of Damage	Standard Deviation of Damage[2]	Mean of Damage	Standard Deviation of Damage[2]
-2	0%	0%	0%	3.0%
-1	2.5%	2.7%	2.4%	2.1%
0	13,4%	2.0%	8.1%	1.5%
1	23.3%	1.6%	13.3%	1.2%
2	32.1%	1.6%	17.9%	1.2%
3	40.1%	1.8%	22.0%	1.4%
4	47.1%	1.9%	25.7%	1.5%
5	53.2%	2.0%	28.8%	1.6%
6	58.6%	2.1%	31.5%	1.6%
7	63.2%	2.2%	33.8%	1.7%
8	67.2%	2.3%	35.7%	1.8%
9	70.5%	2.4%	37.2%	1.9%
10	73.2%	2.7%	38.4%	2.1%
11	75.4%	3.0%	39.2%	2.3%
12	77.2%	3.3%	39.7%	2.6%
13	78.5%	3.7%	40.0%	2.9%
14	79.5%	4.1%	39.9%	3.2%
15	80.2%	4.5%	39.6%	3.5%
16	80.7%	4.9%	39.1%	3.8%

Notes:
1. Expressed as a percent of structural value.
2. Because these curves were received after the completion of the @RISK file templates, the Comprehensive Study used only the maximum standard deviation (5%) rather than stage-specific standard deviations. This would mean that the analysis includes more uncertainty for the lower depths than indicated by this table.
Source: USACE, Institute for Water Resources, Depth-Damage Functions for Corps of Engineers Flood Damage Reduction Studies.

Agricultural Depth-Damage Relationships

Because of the extensive agricultural acreage currently within the floodplains in both basins (about 1.6 million irrigated acres out of the total 2.2 million acres), crop flood damage analysis is an important element in the Comprehensive Study. It is recognized that over 100 different crops are grown within the Comprehensive Study area; however, for analytical purposes only the predominant crops were evaluated: field crops (corn, beans, wheat, cotton, safflower), fruit crops (almonds, walnuts, peaches, pears, prunes), alfalfa, mixed pasture, rice, truck crops (melons, tomatoes), and vine crops. However, less predominate crops were also included by using a surrogate crop type from the above list. Table 10 summarizes the acreages and annual production values of the crop types included in the Comprehensive Study. The types of agricultural flood damage being evaluated include the loss of direct production costs incurred prior to flooding, the loss of net value (income) of crop, the loss of depreciated value of perennial crops, and land clean up and rehabilitation costs. In addition to flood depths, the effects of seasonality and flooding duration are considered in the computation of agricultural flood damages for each crop. These two factors are often more important than flood depths.

TABLE 10
CROP ACREAGES AND PRODUCTION VALUES

Crops	Sacramento Basin[1]		San Joaquin Basin		Total	
	Acres	Value ($Mill)	Acres	Value ($Mill)	Acres	Value ($Mill)
Fruits and Nuts	221,856	$548	25,412	$61	247,268	$610
Field Crops	327,995	$122	206,666	$155	534,661	$277
Pasture and Alfalfa	73,671	$32	132,903	$84	206,574	$117
Rice	372,448	$323	404	$0	372,852	$323
Truck Crops	113,077	$244	50,118	$107	163,195	$351
Vine Crops	5,314	$20	21,399	$79	26,713	$98
Total	**1,114,361**	**$1,290**	**436,902**	**$487**	**1,551,263**	**$1,776**

Notes:
1. Includes the Upper Sacramento reach (Vina to Keswick)

Expected Annual Damage

Preliminary existing condition expected annual damage and project performance statistics have been completed for both basins. For both basins combined, existing condition expected annual damage is over $280 million (October 2001 price levels). Most of the damage is expected to occur in the Sacramento River basin (including Upper Sacramento), with about $251 million EAD compared to about $31 million EAD within the San Joaquin River basin. The distribution of damage within the two basins is significantly different, with urban structural damage (residential, commercial, industrial, etc.) representing about 77 percent of total Sacramento River basin EAD compared to about 39 percent within the San Joaquin River basin.

Figures 5 through 7 compare existing condition EAD estimates for both basins. Tables 11 and 12 show existing condition EAD by impact areas for the Sacramento and San Joaquin

river basins, respectively. One reason for the large difference in damage between the two basins is that there are several large cities and smaller communities located completely within the Sacramento River basin floodplains whereas, in the San Joaquin River basin, most of the larger cities and smaller communities along Interstate 5 (to the west) and State Highway 99 (to the east) are located outside of the floodplain.

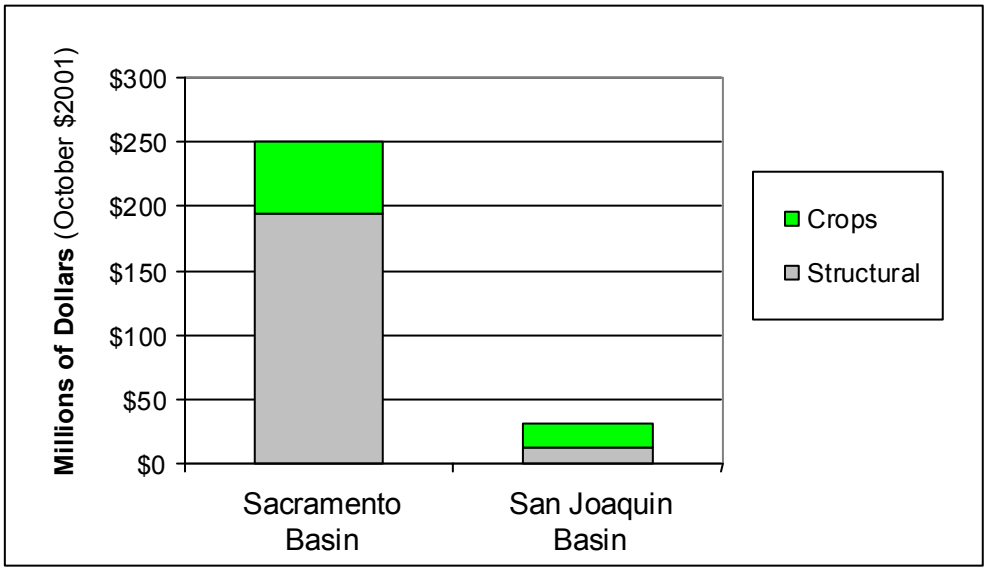


FIGURE 5 – COMPARISON OF SACRAMENTO AND SAN JOAQUIN RIVER BASINS EXPECTED ANNUAL DAMAGE, EXISTING CONDITIONS

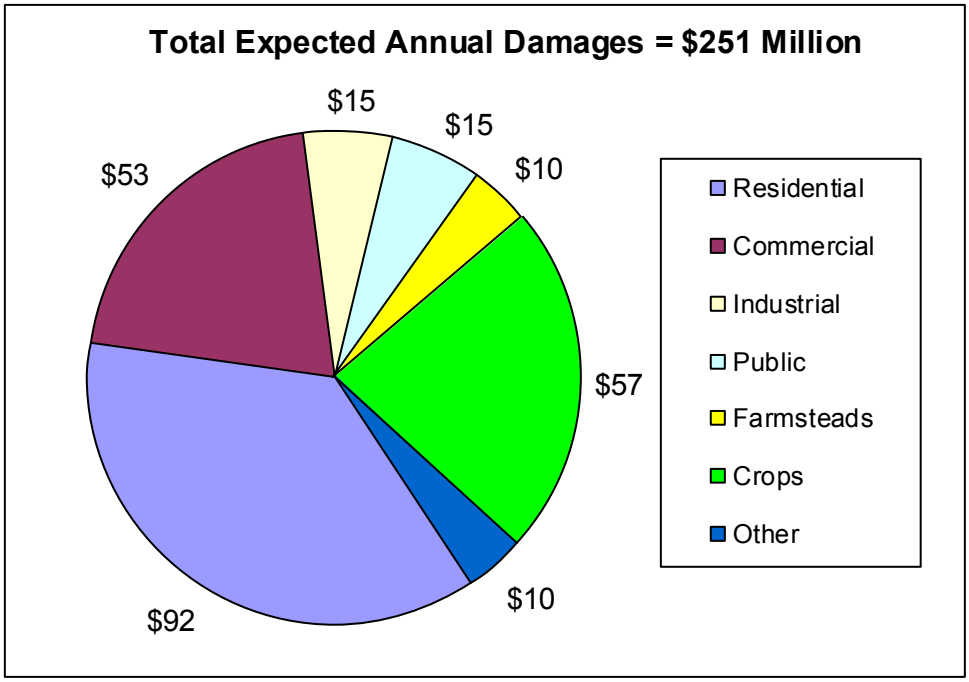


FIGURE 6 – SACRAMENTO RIVER BASIN EXPECTED FLOOD DAMAGE, EXISTING CONDITIONS

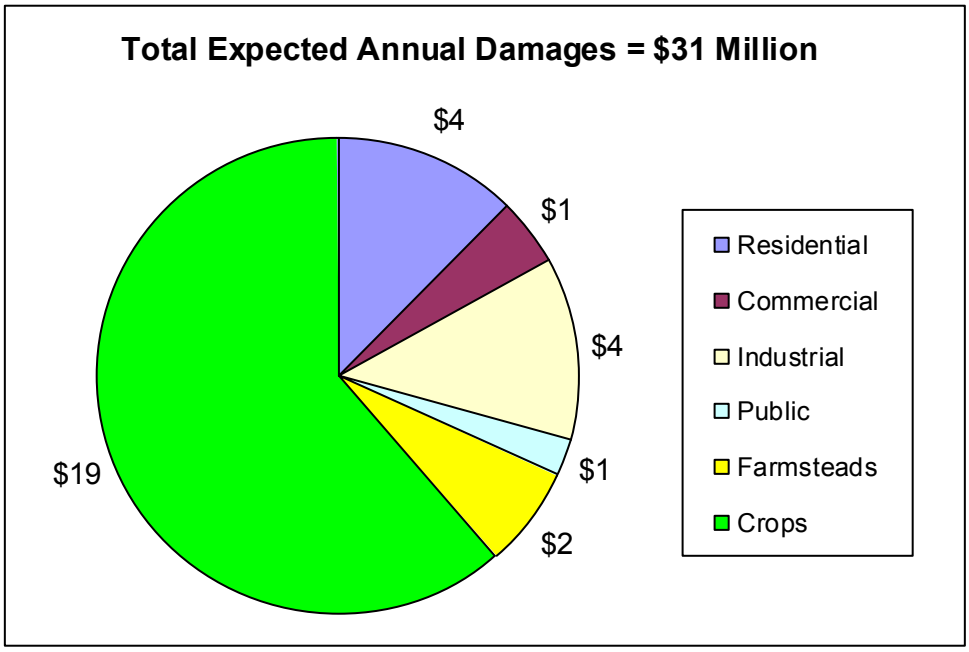


FIGURE 7 – SAN JOAQUIN RIVER BASIN EXPECTED FLOOD DAMAGE, EXISTING CONDITIONS

TABLE 11
SACRAMENTO RIVER BASIN EXPECTED ANNUAL DAMAGE, EXISTING CONDITIONS

(THOUSANDS OF OCTOBER $2001)

Impact Area No.	Impact Area Name	Expected Annual Damage	Impact Area No.	Impact Area Name	Expected Annual Damage
Upper Sacramento					
US 1	Redding	200	US 4	Los Molinos	260
US 2	Anderson	609	US 5	Red Bluff	656
US 3	Bend	175	US 6	Tehama	4
				Subtotal	*1,905*
Sacramento					
1	Woodson Bridge East	3,825	32	Rec Dist 70-1660	1,116
2	Woodson Bridge West	431	33	Meridian	28
3	Hamilton City	354	34	Rec Dist 1500 East	4,278
4	Capay	2,386	35	Elkhorn	6,356
5	Butte Basin	4,577	36	Natomas	42,590
6	Butte City	59	37	Rio Linda	3,920
7	Colusa Basin North	4,458	38	West Sacramento	3,309
8	Colusa	3,544	39	Rec Dist 900	355
9	Colusa Basin South	23,875	40	Sacramento	93,366
10	Grimes	297	41	Rec Dist 302	17
11	Rec Dist 1500 West	7,272	42	Rec Dist 999	110
12	Sycamore Slough	1,053	43	Clarksburg	36
13	Knight's Landing	492	44	Stone Lake	293
14	Ridge Cut (North)	75	45	Hood	1
15	Ridge Cut (South)	36	46	Merritt Island	21
16	Rec Dist 2035	126	47	Rec Dist 551	165
17	East of Davis	212	48	Courtland	3
18	Honcut	165	49	Sutter Island	487
19	Sutter Buttes North	44	50	Grand Island	2,565
20	Gridley	23	51	Locke	33
21	Sutter Buttes East	198	52	Walnut Grove	46
22	Live Oak	135	53	Tyler Island	3,714
23	District 10	214	54	Andrus Island	16,947
24	Levee Dist. #1	1,579	55	Ryer Island	808
25	Yuba City	4,458	56	Prospect Island	75
26	Marysville	878	57	Twitchell Island	20
27	Linda-Olivehurst	652	58	Sherman Island	1,725
28	Rec Dist 384	194	59	Moore	585
29	Best Slough	163	60	Cache Slough	340
30	Rec Dist 1001	3,641	61	Hastings	331
31	Sutter Buttes South	74	62	Lindsey Slough	33
				Total Sacramento $	**251,427**

TABLE 12
SAN JOAQUIN RIVER BASIN EXPECTED ANNUAL DAMAGE, EXISTING CONDITIONS

(THOUSANDS OF OCTOBER $2001)

Impact Area No.	Impact Area Name	Expected Annual Damage	Impact Area No.	Impact Area Name	Expected Annual Damage
1	Fresno	122	22	Orestimba	20
2	Fresno Slough East	170	23	Tuolumne South	2,092
3	Fresno Slough West	505	24	Tuolumne River	119
4	Mendota	122	25	Modesto	1,432
5	Chowchilla Bypass	230	26	3 Amigos	1,137
6	Lone Willow Slough	1,062	27	Stanislaus South	779
7	Mendota North	78	28	Stanislaus North	1,297
8	Firebaugh	65	29	Banta Carbona	283
9	Salt Slough	2,375	30	Paradise Cut	125
10	Dos Palos	9	31	Stewart Tract	338
11	Fresno River	216	32	East Lathrop	125
12	Berenda Slough	3,506	33	Lathrop/ Sharpe	1,141
13	Ash Slough	1,127	34	French Camp	1,882
14	Sandy Mush	78	35	Moss Tract	2,742
15	Turner Island	1,114	36	Roberts Island	2,343
16	Bear Creek	35	37	Rough and Ready Island	351
17	Deep Slough	60	38	Drexler Tract	493
18	West Bear Creek	335	39	Union Island	1,180
19	Fremont Ford	55	40	Southeast Union Island	70
20	Merced River	226	41	Fabian Tract	45
21	Merced River North	1,792	42	RD 1007	65
				Total San Joaquin $	**31,341**

Within the Sacramento River Basin, 90% of the population resides in only eight of the 62 impact areas. These impact areas are primarily located in the Sacramento metropolitan area, Colusa and along the Feather River (for example, Marysville/Yuba City). Most of the population within these impact areas is protected by levees and is thus subject to a relatively infrequent but potentially severe flooding risk. Almost 70% of the non-agricultural expected annual damage is within two impact areas—Sacramento and Natomas. Population within the San Joaquin River basin is more dispersed than in the Sacramento River basin. For example, 90% of the San Joaquin population is located in 16 impact areas (compared to eight for the Sacramento River basin). One factor affecting this is the greater proportion of farmsteads in the San Joaquin River basin compared to the Sacramento. Farmsteads of course are not located in urbanized areas but are instead spread out throughout the basin. As a result, flood damage is more dispersed throughout the San Joaquin basin than the Sacramento basin—about 72% of the non-agricultural damage is found within five impact areas.

Project Performance

Tables 13 and 14 present the project performance statistics for both basins. The three indicators of project performance estimated by the HEC-FDA model include expected annual exceedance probability, long-term risk, and conditional non-exceedance probability.

Expected annual exceedance probability is a key element in defining the performance of a flood management project. It is the probability that a specific capacity or target stage will be exceeded in a given year.[8] For example, if the expected annual exceedance probability is estimated to be 0.020, then there is a two percent chance of a damaging flood event along that particular river reach in any given year. If levees are located along the river reach (which is the case for most reaches along the Sacramento and San Joaquin rivers), the chance of their failure is also taken into account.

Long-term risk is the probability of a target stage being exceeded during a specified period. For example, if the long-term risk for a 25-year period is estimated to be 0.100, then there is a 10 percent chance that there will be one or more events that exceed a specified target stage during that time frame. HEC-FDA estimates long-term risk for 10-, 25- and 50 year periods.

Conditional non-exceedance probability is the probability that a specified event will be contained by a project. If levees are involved, this statistic includes both the chance of levee overtopping as well as the chance of failure at lower stages. For example, if the conditional non-exceedance probability is 0.750 for a 2% (i.e., 1 in 50-year) event, then there is a 75 percent chance that the target stage will <u>not</u> be exceeded for that particular flood event. Thus, while the expected annual exceedance and long-term risk probabilities measure the susceptibility of areas to flooding, conditional non-exceedance probability measures their ability to survive specified flood events. HEC-FDA generates conditional non-exceedance probabilities for the 10%, 4%, 2%, 1%, 0.4%, and 0.2% events.

As discussed above, project performance statistics are not available for the Upper Sacramento reach because of insufficient hydraulics data and therefore the use of a different approach to estimate flood damage.

[8] Target stage is the maximum stage possible before any significant flood damage is incurred.

TABLE 13
SACRAMENTO RIVER BASIN PROJECT PERFORMANCE STATISTICS, EXISTING CONDITIONS

Impact Area	Impact Area Name	Annual Exceedance Probability (Expected)	Long Term Risk			Conditional Non-Exceedance Probability by Flood Event					
			10 Years	25 Years	50 Years	10%	4%	2%	1%	0.40%	0.20%
SAC01	Woodson Br East	0.1400	0.7778	0.9767	0.9995	0.2356	0.0075	0.0000	0.0000	0.0000	0.0000
SAC02	Woodson Br West	0.1870	0.8734	0.9943	1.0000	0.0659	0.0010	0.0000	0.0000	0.0000	0.0000
SAC03	Hamilton City	0.4860	0.9987	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SAC04	Capay	0.4860	0.9987	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SAC05	Butte Basin	0.1550	0.8141	0.9851	0.9998	0.0403	0.0018	0.0000	0.0000	0.0000	0.0000
SAC06	Butte City	0.1540	0.8129	0.9849	0.9998	0.0406	0.0014	0.0000	0.0000	0.0000	0.0000
SAC07	Colusa Basin North	0.4380	0.9969	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SAC08	Colusa	0.3690	0.9901	1.0000	1.0000	0.4862	0.4038	0.3225	0.2288	0.0031	0.0000
SAC09	Colusa Basin South	0.5190	0.9993	1.0000	1.0000	0.3382	0.1163	0.0027	0.0000	0.0000	0.0000
SAC10	Grimes	0.5180	0.9993	1.0000	1.0000	0.3390	0.1176	0.0029	0.0000	0.0000	0.0000
SAC11	Rec Dist 1500 West	0.2540	0.9467	0.9993	1.0000	0.5042	0.0648	0.0100	0.0000	0.0000	0.0000
SAC12	Sycamore Slough	0.1140	0.7002	0.9508	0.9976	0.7133	0.3165	0.1750	0.0267	0.0000	0.0000
SAC13	Knight's Landing	0.0700	0.5155	0.8366	0.9733	0.8227	0.3948	0.2753	0.0871	0.0000	0.0000
SAC14	Ridge Cut North	0.1250	0.7368	0.9645	0.9987	0.6217	0.5669	0.5167	0.3437	0.0012	0.0000
SAC15	Ridge Cut South	0.0740	0.5368	0.8540	0.9787	0.6901	0.3614	0.2567	0.1196	0.0000	0.0000
SAC16	RD2035	0.0790	0.5631	0.8738	0.9841	0.6859	0.5905	0.5481	0.5300	0.0620	0.0000
SAC 17	East of Davis	0.0400	0.3380	0.6435	0.8729	1.0000	0.5463	0.0021	0.0000	0.0000	0.0000
SAC18	Honcut	0.0260	0.2346	0.4874	0.7372	1.0000	0.7576	0.4562	0.1972	0.0707	0.0210
SAC19	Sutter Buttes North	0.0010	0.0135	0.0330	0.0656	1.0000	0.9951	0.9950	0.9949	0.9159	0.3912
SAC20	Gridley	0.0010	0.0116	0.0288	0.0568	1.0000	0.9950	0.9949	0.9948	0.9152	0.3920
SAC21	Sutter Buttes East	0.0030	0.0280	0.0685	0.1323	1.0000	1.0000	1.0000	1.0000	0.9188	0.0991
SAC22	Live Oak	0.0030	0.0301	0.0736	0.1418	1.0000	1.0000	1.0000	1.0000	0.8653	0.0973
SAC23	District 10	0.0030	0.0298	0.0729	0.1405	1.0000	1.0000	1.0000	0.9969	0.8612	0.0638
SAC24	Levee District 1	0.0760	0.5476	0.8623	0.9810	0.6772	0.3377	0.2594	0.0863	0.0000	0.0000
SAC25	Yuba City	0.0100	0.0979	0.2271	0.4027	1.0000	0.9119	0.8764	0.8074	0.2296	0.0019
SAC26	Marysville	0.0050	0.0486	0.1172	0.2207	1.0000	0.9897	0.9813	0.9552	0.6036	0.0064
SAC27	Linda-Olivehurst	0.0360	0.3100	0.6045	0.8436	0.9880	0.5989	0.3015	0.0983	0.0345	0.0131
SAC28	RD784	0.0100	0.0992	0.2299	0.4070	1.0000	0.9287	0.8673	0.7864	0.2069	0.0000
SAC29	Best Slough	0.0650	0.4889	0.8132	0.9651	0.7299	0.4256	0.2106	0.0734	0.0721	0.0713
SAC30	RD1001	0.0790	0.5594	0.8711	0.9834	0.6472	0.4960	0.4421	0.3209	0.0035	0.0000
SAC31	Sutter Buttes South	0.0380	0.3204	0.6193	0.8550	0.8694	0.7214	0.5960	0.4835	0.0351	0.0000
SAC32	RD70/1660	0.0400	0.3353	0.6398	0.8702	0.8524	0.7122	0.5850	0.4680	0.3564	0.0981
SAC33	Meridian	0.0420	0.3478	0.6564	0.8820	0.8525	0.7123	0.5849	0.4406	0.0237	0.0000
SAC34	RD1500 East	0.2550	0.9472	0.9994	1.0000	0.5031	0.0644	0.0102	0.0000	0.0000	0.0000
SAC35	Elkhorn	0.4990	0.9990	1.0000	1.0000	0.0023	0.0000	0.0000	0.0000	0.0000	0.0000
SAC36	Natomas	0.0200	0.1869	0.4039	0.6447	0.9924	0.8062	0.6539	0.6029	0.0126	0.0000
SAC37	Rio Linda	0.0060	0.0608	0.1452	0.2693	1.0000	1.0000	1.0000	1.0000	0.0190	0.0000
SAC38	West Sacramento	0.0070	0.0691	0.1639	0.3009	1.0000	1.0000	0.9967	0.9808	0.0208	0.0000
SAC39	RD900	0.0050	0.0493	0.1186	0.2232	1.0000	1.0000	1.0000	1.0000	0.2393	0.0089
SAC40	Sacramento	0.0100	0.0918	0.2140	0.3823	0.9837	0.9826	0.9819	0.9517	0.0000	0.0000
SAC41	RD302	0.0060	0.0606	0.1446	0.2684	1.0000	1.0000	1.0000	0.9971	0.0684	0.0021
SAC42	RD999	0.1220	0.7276	0.9613	0.9985	0.6032	0.5683	0.5521	0.4847	0.0216	0.0000
SAC43	Clarksburg	0.1220	0.7276	0.9613	0.9985	0.6032	0.5683	0.5521	0.4847	0.0216	0.0000
SAC44	Stone Lake	0.1000	0.6508	0.9280	0.9948	0.5882	0.5004	0.4865	0.3488	0.0000	0.0000
SAC45	Hood	0.1000	0.6509	0.9280	0.9948	0.5894	0.4877	0.4752	0.3502	0.0000	0.0000
SAC46	Merritt Island	0.1510	0.8054	0.9833	0.9997	0.4893	0.0727	0.0212	0.0045	0.0000	0.0000
SAC47	RD551	0.0370	0.3172	0.6148	0.8516	0.8188	0.7555	0.6821	0.5548	0.0069	0.0000
SAC48	Courtland	0.0370	0.3176	0.6153	0.8520	0.8179	0.7549	0.6815	0.5543	0.0063	0.0000

TABLE 13 (CONT.)

Impact Area	Impact Area Name	Annual Exceedance Probability (Expected)	Long Term Risk			Conditional Non-Exceedance Probability by Flood Event					
			10 Years	25 Years	50 Years	10%	4%	2%	1%	0.40%	0.20%
SAC49	Sutter Island	0.1050	0.6694	0.9372	0.9961	0.6025	0.0000	0.0000	0.0000	0.0000	0.0000
SAC50	Grand Island	0.1160	0.7075	0.9537	0.9979	0.6188	0.0000	0.0000	0.0000	0.0000	0.0000
SAC51	Locke	0.0260	0.2305	0.4807	0.7303	0.9744	0.7931	0.7163	0.1445	0.0000	0.0000
SAC52	Walnut Grove	0.0340	0.2951	0.5829	0.8260	0.9113	0.6957	0.5171	0.5104	0.0000	0.0000
SAC53	Tyler Island	0.8490	1.0000	1.0000	1.0000	0.0023	0.0000	0.0000	0.0000	0.0000	0.0000
SAC54	Andrus Island	0.6710	1.0000	1.0000	1.0000	0.1599	0.1209	0.0605	0.0000	0.0000	0.0000
SAC55	Ryer Island	0.1310	0.7557	0.9705	0.9991	0.4556	0.0000	0.0000	0.0000	0.0000	0.0000
SAC56	Prospect Island	0.3130	0.9766	0.9999	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SAC57	Twitchell Island	0.3050	0.9736	0.9999	1.0000	0.6120	0.5493	0.4936	0.1944	0.0000	0.0013
SAC58	Sherman Island	0.5810	0.9998	1.0000	1.0000	0.2837	0.2558	0.2267	0.1897	0.0000	0.0000
SAC59	Moore	0.1260	0.7407	0.9658	0.9988	0.0225	0.0000	0.0000	0.0000	0.0000	0.0000
SAC60	Cache Slough	0.0660	0.4949	0.8187	0.9671	0.9600	0.0343	0.0044	0.0174	0.0000	0.0000
SAC61	Hastings	0.3370	0.9835	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SAC62	Lindsey Slough	0.0130	0.1215	0.2766	0.4767	1.0000	1.0000	0.7375	0.5036	0.0030	0.0000

TABLE 14
SAN JOAQUIN RIVER BASIN PROJECT PERFORMANCE STATISTICS, EXISTING CONDITIONS

Impact Area	Impact Area Name	Annual Exceedance Probability (Expected)	Long Term Risk			Conditional Non-Exceedance Probability by Flood Event					
			10 Years	25 Years	50 Years	10%	4%	2%	1%	0.40%	0.20%
SJ 01	Fresno	0.0170	0.1548	0.3433	0.5688	0.9976	0.9976	0.9521	0.0003	0.0000	0.0000
SJ 02	Fresno Slough East	0.0280	0.2436	0.5023	0.7523	0.9942	0.9690	0.1795	0.0001	0.0000	0.0000
SJ 03	Fresno Sl West	0.4970	0.9990	1.0000	1.0000	0.4937	0.2502	0.2477	0.2452	0.0000	0.0000
SJ 04	Mendota	0.3280	0.9813	1.0000	1.0000	0.4531	0.2857	0.2834	0.2787	0.0000	0.0000
SJ 05	Chowchilla Bypass	0.0340	0.2940	0.5812	0.8246	0.9630	0.8810	0.0955	0.0001	0.0000	0.0000
SJ 06	Lone Willow Sl	0.1110	0.6912	0.9470	0.9972	0.7092	0.0001	0.0000	0.0000	0.0000	0.0000
SJ 07	Mendota North	0.0900	0.6112	0.9057	0.9911	0.5920	0.3008	0.2874	0.2780	0.0017	0.0000
SJ 08	Firebaugh	0.0700	0.5150	0.8362	0.9732	0.7395	0.5397	0.0034	0.0033	0.0000	0.0000
SJ 09	Salt Slough	0.1390	0.7750	0.9760	0.9994	0.4292	0.1704	0.1293	0.1243	0.0000	0.0000
SJ 10	Dos Palos	0.1380	0.7738	0.9757	0.9994	0.4323	0.1852	0.1084	0.1062	0.0000	0.0000
SJ 11	Fresno River	0.1320	0.7562	0.9707	0.9991	0.5144	0.1665	0.1154	0.1092	0.0000	0.0000
SJ 12	Berenda Slough	0.4500	0.9975	1.0000	1.0000	0.0015	0.0001	0.0001	0.0001	0.0000	0.0000
SJ 13	Ash Slough	0.3030	0.9731	0.9999	1.0000	0.1014	0.0001	0.0000	0.0000	0.0000	0.0000
SJ 14	Sandy Mush	0.0910	0.6158	0.9085	0.9916	0.5706	0.5680	0.4708	0.0000	0.0000	0.0000
SJ 15	Turner Island	0.1310	0.7535	0.9698	0.9991	0.5362	0.0028	0.0000	0.0000	0.0000	0.0000
SJ 16	Bear Creek	0.0550	0.4342	0.7592	0.9420	0.8674	0.5322	0.4780	0.1019	0.0000	0.0000
SJ 17	Deep Slough	0.0650	0.4900	0.8143	0.9655	0.7933	0.5318	0.3788	0.0000	0.0000	0.0000
SJ 18	West Bear Creek	0.1310	0.7535	0.9698	0.9991	0.4464	0.1465	0.0168	0.0000	0.0000	0.0000
SJ 19	Fremont Ford	0.2370	0.9330	0.9988	1.0000	0.2019	0.0000	0.0000	0.0000	0.0000	0.0000
SJ 20	Merced River	0.1680	0.8414	0.9900	0.9999	0.3111	0.3036	0.0000	0.0000	0.0000	0.0000
SJ 21	Merced R North	0.5460	0.9996	1.0000	1.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0001
SJ 22	Orestimba	0.0090	0.0851	0.1994	0.3590	0.9972	0.9972	0.9811	0.7473	0.0000	0.0000
SJ 23	Tuolumne South	0.3070	0.9743	0.9999	1.0000	0.2981	0.0271	0.0000	0.0000	0.0004	0.0000
SJ 24	Tuolumne River	0.0060	0.0623	0.1486	0.2752	0.9974	0.9974	0.9974	0.9902	0.0559	0.0000
SJ 25	Modesto	0.0130	0.1225	0.2788	0.4799	0.9974	0.9974	0.9974	0.0393	0.0000	0.0000
SJ 26	3 Amigos	0.8540	1.0000	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SJ 27	Stanislaus South	0.6260	0.9999	1.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
SJ 28	Stanislaus North	0.3140	0.9770	0.9999	1.0000	0.0032	0.0000	0.0000	0.0000	0.0001	0.0000
SJ 29	Banta Carbona	0.2720	0.9580	0.9996	1.0000	0.2236	0.0174	0.0000	0.0000	0.0000	0.0000
SJ 30	Paradise Cut	0.3120	0.9764	0.9999	1.0000	0.3025	0.0037	0.0000	0.0000	0.0000	0.0000
SJ 31	Stewart Tract	0.3120	0.9762	0.9999	1.0000	0.2721	0.0146	0.0000	0.0000	0.0000	0.0000
SJ 32	East Lathrop	0.3080	0.9749	0.9999	1.0000	0.2397	0.0272	0.0096	0.0002	0.0000	0.0000
SJ 33	Lathrop/Sharpe	0.2220	0.9192	0.9981	1.0000	0.2542	0.0009	0.0005	0.0000	0.0000	0.0000
SJ 34	French Camp	0.2220	0.9191	0.9981	1.0000	0.2542	0.0009	0.0005	0.0000	0.0000	0.0000
SJ 35	Moss Tract	0.2230	0.9203	0.9982	1.0000	0.2435	0.0340	0.0006	0.0000	0.0000	0.0000
SJ 36	Roberts Island	0.3720	0.9905	1.0000	1.0000	0.2193	0.0050	0.0000	0.0000	0.0000	0.0000
SJ 37	Rough & Ready Is	0.2470	0.9417	0.9992	1.0000	0.1780	0.0721	0.0155	0.0000	0.0000	0.0000
SJ 38	Drexler Tract	0.3540	0.9874	1.0000	1.0000	0.2380	0.0290	0.0000	0.0000	0.0000	0.0000
SJ 39	Union Island	0.3210	0.9793	0.9999	1.0000	0.2405	0.0600	0.0003	0.0000	0.0000	0.0000
SJ 40	SE Union Island	0.2180	0.9147	0.9979	1.0000	0.2462	0.0297	0.0037	0.0000	0.0000	0.0000
SJ 41	Fabian Tract	0.2240	0.9205	0.9982	1.0000	0.2259	0.0119	0.0001	0.0000	0.0000	0.0000
SJ 42	RD 1007	0.2140	0.9097	0.9975	1.0000	0.2516	0.0181	0.0002	0.0000	0.0000	0.0000

Population at Risk

Population at risk was approximated by multiplying the number of residential parcels in the floodplains by 2001 CA Department of Finance population/housing units' data for counties within the floodplains. Residential structures include single and multi-family units, mobile homes, and farmsteads. While this approach works reasonably well for single family and farmstead units (where one structure can be assumed per parcel) and, to lesser extent mobile homes, it does not work well for parcels that might contain multiple housing units, such as apartments, condominiums, etc. Unfortunately, information concerning the numbers of these types of housing units per parcel has not been obtained. However, to account for the population living in multiple unit housing units within the floodplains, the estimate of single family/farmstead/mobile home population was increased based upon the proportion of county households living in multiple family units. This percentage was about 25 percent for counties within the Sacramento River basin and about 23 percent for counties within the San Joaquin River basin. These estimates can be revised when more detailed feasibility studies are conducted. Table 15 shows the derivation of the population at risk estimates.

TABLE 15
POPULATION AT RISK

Parcels/Population	Sacramento Basin	San Joaquin Basin	Total
Parcel Type			
Single Family	159,502	9,752	169,254
Mobile Homes	1,493	218	1,711
Farmsteads	3,336	1,976	5,312
Total	*164,331*	*11,946*	*176,277*
Basin Pop/Household[1]	2.66	3.01	-------
Population (w/o multi-family units)	437,121	35,957	473,078
Multi-family unit factor[2]	1.25	1.23	-------
Population (with multi-family units)	546,401	44,228	590,629

1. Source: CA Department of Finance, Report E5: City/County Population
2. Proportion of population residing in multi-family units; CA DOF.

Future "Without Project" Conditions

The estimation of existing condition expected annual damage is only part of the "without project" analysis. Future "without project" population and economic development levels, and associated flood damage, have not been estimated. Although Corps guidance generally requires that projects be shown to be cost-effective based upon existing conditions, a complete analysis should take into account future development likely to occur with and without proposed alternatives. A complete "without project" analysis including future development will be conducted during later studies of specific alternatives.

BASIN-WIDE EVALUATIONS

A tremendous amount of time and resources were required to run the hydraulic and economic models for the base condition analysis. Consequently, a modified evaluation process was used to expedite preliminary basin-wide evaluations, which provided information on how the basins would respond to various changes to the flood management systems. The process initially focused upon changes in project performance at several representative locations, providing information concerning overall hydraulic performance. Although the process did not provide information on the change in basin-wide damages, it was believed that if the hydraulic performance improved over existing conditions for most (if not all) of the representative locations, then it could reasonably expected that flood damages for the entire basin would also be reduced.

The impact areas within each river basin were grouped into larger "bubble" impact areas and an indicator impact area was identified within each bubble to represent the group, as shown in Table 16. For the Sacramento basin, nine bubble impact areas were identified from the original 62 impact areas, shown in Figure 8. Similarly, seven bubble impact areas were identified in the San Joaquin River basin from the original 42 impact areas, shown in Figure 9. The preliminary basin-wide evaluations focused primarily upon project performance statistics for these bubble impact areas.

TABLE 16
BUBBLE IMPACT AREAS FOR THE ALTERNATIVES ANALYSIS

Sacramento River Basin		San Joaquin River Basin	
Bubble Impact Area	**Indicator Impact Area**	**Bubble Impact Area**	**Indicator Impact Area**
SAC-A	SAC09 – Colusa Basin South	SJ-A	SJ5 – Chowchilla Bypass
SAC-B	SAC21 – Sutter Buttes East	SJ-B	SJ09 – Salt Slough
SAC-C	SAC24 – Levee Dist. No. 1	SJ-C	SJ13 – Ash Slough
SAC-D	SAC11 – RD 1500 West	SJ-D	SJ19 – Fremont Ford
SAC-E	SAC35 - Elkhorn	SJ-E	SJ22 - Orestimba
SAC-F	SAC40 - Sacramento	SJ-F	SJ26 – 3 Amigos
SAC-G	SAC61 - Hastings	SJ-G	SJ29 – Banta Carbona
SAC-H	SAC44 – Stone Lake		
SAC-I	SAC 7 - Colusa Basin North		

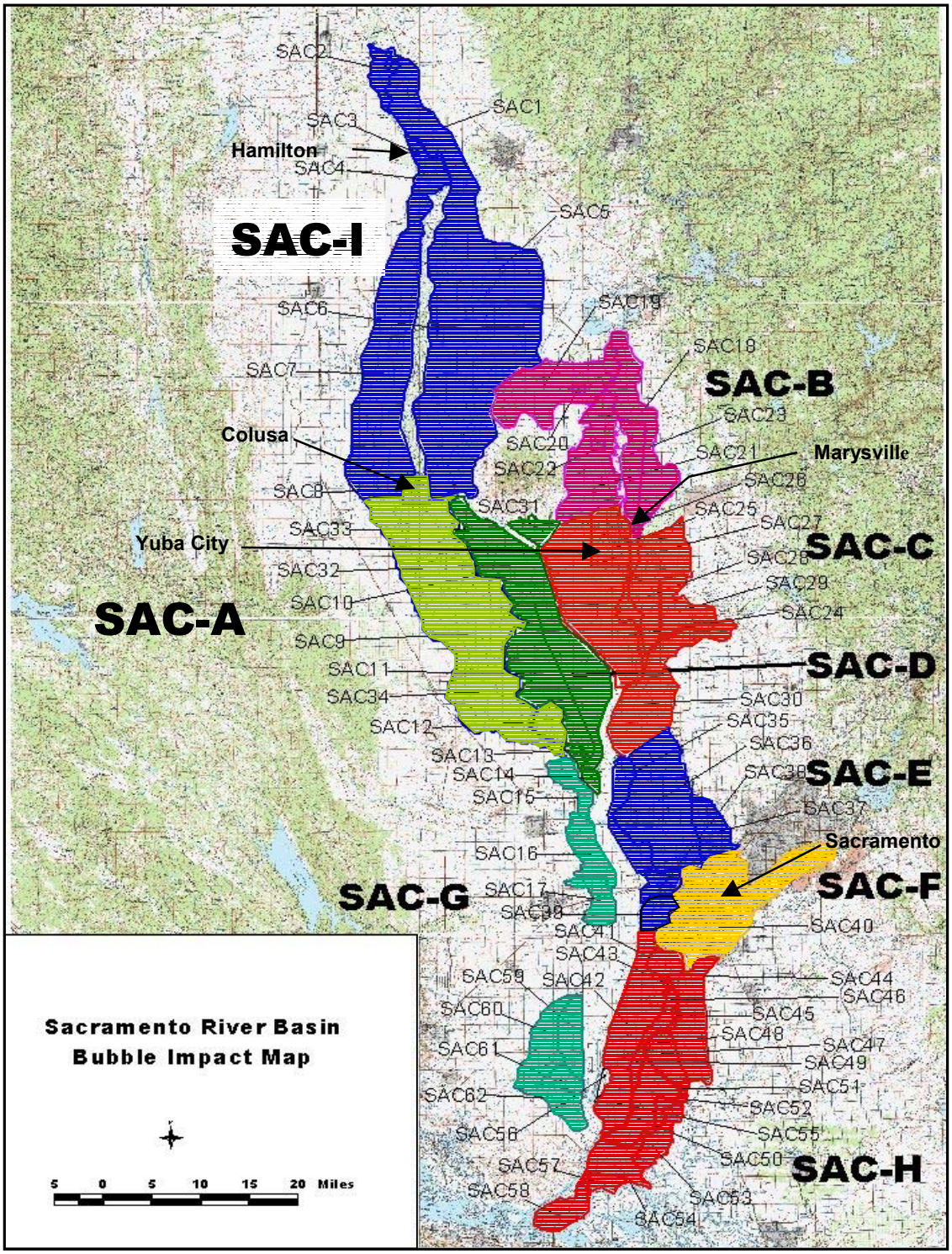


FIGURE 8 - SACRAMENTO RIVER BASIN BUBBLE IMPACT AREAS

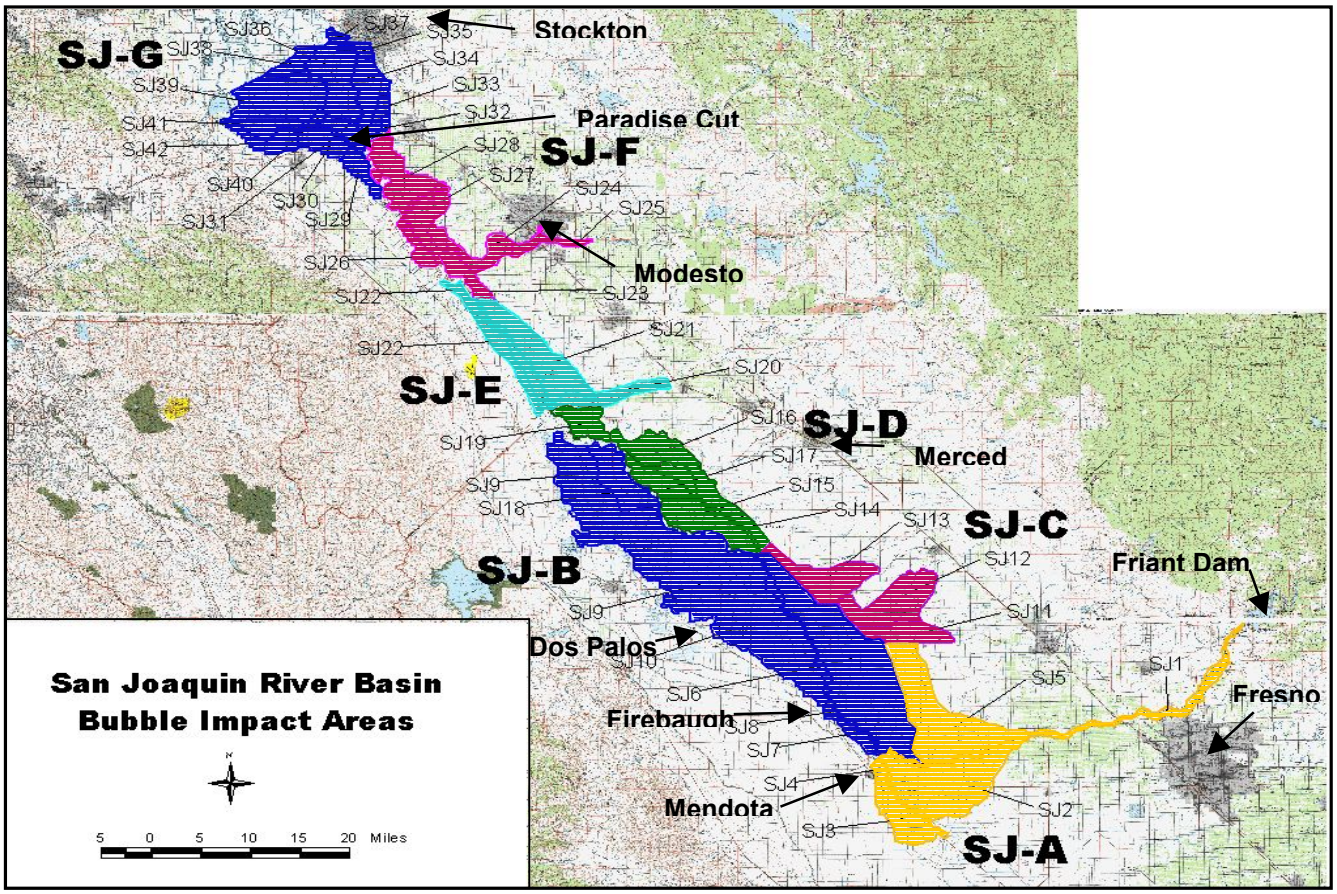


FIGURE 9 - SAN JOAQUIN RIVER BASIN BUBBLE IMPACT AREAS

River Corridor Evaluations

The HEC-FDA models were used to evaluate a range of river corridor or floodway modification scenarios. The objective of these evaluations was to gain experience using the various Comprehensive Study modeling tools – reservoir operations, hydraulic, risk and economics models – and learn how the system could react to different flood damage reduction and ecosystem improvement scenarios. Modeling for these alternatives was performed in stages to display a range of ways in which the flood management system could be modified in combination with new flood storage. These preliminary evaluations were not intended to represent alternative plans. The HEC-FDA analysis of these evaluations was restricted to project performance, and a detailed accounting of economic and environmental benefits was not performed.

To illustrate this process, Figure 10 shows an example project performance analysis for a hypothetical bubble impact area (SJ-EX). The top panel compares annual exceedance probabilities for existing conditions with two "river corridor" scenarios - with and without additional flood storage. Both scenarios resulted in lower annual exceedance than for existing conditions; thus, both represent an improvement. Similarly, long-term risk is lower for both scenarios compared to existing conditions. Both scenarios also have improved non-exceedance values (i.e., the ability to pass specific events) for the 10-, 25-, and 50-return

frequency events, although values for the 100- year return frequency event are slightly less than existing conditions.

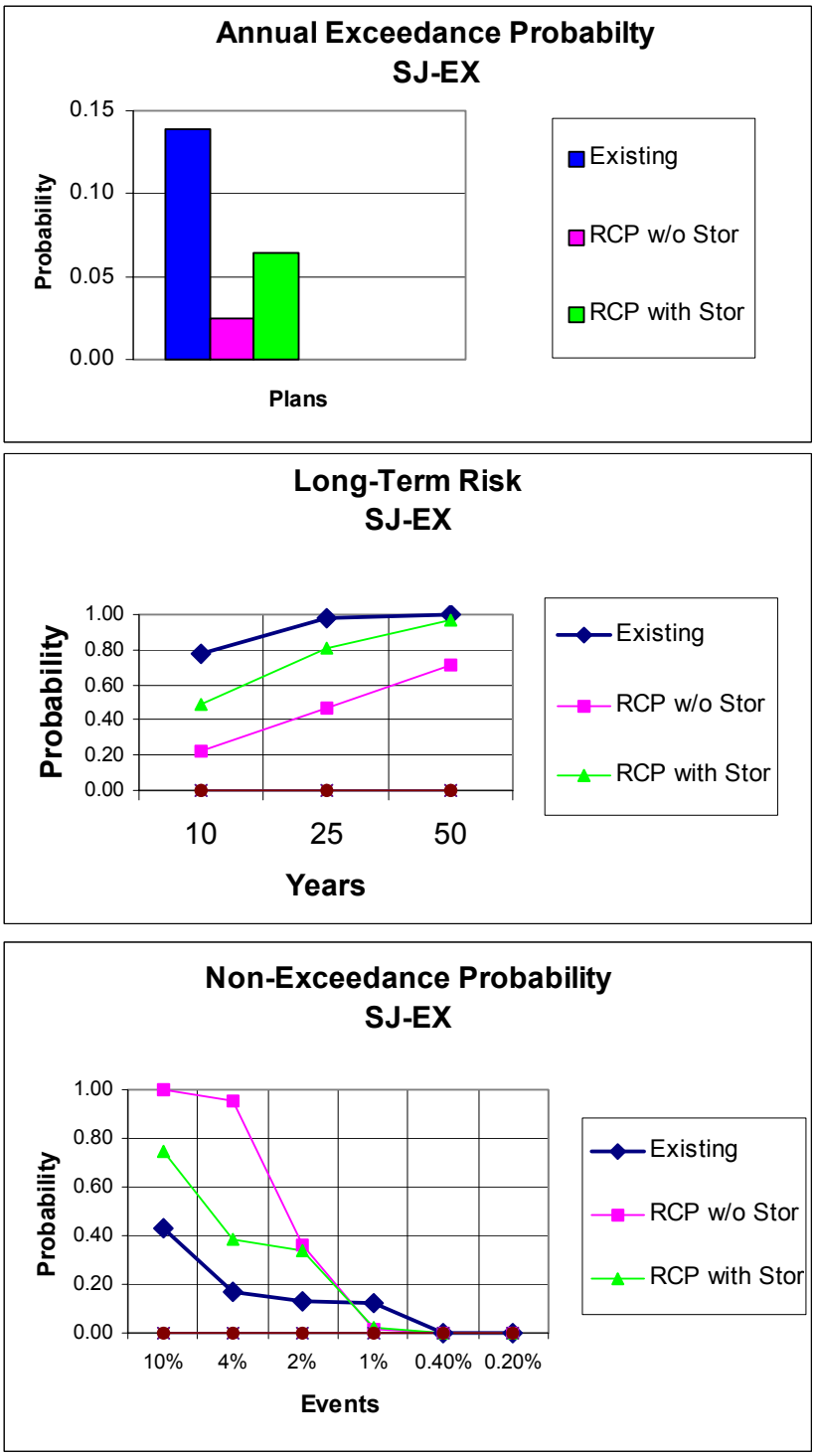


FIGURE 10 - EXAMPLE PROJECT PERFORMANCE ANALYSIS USING BUBBLE IMPACT AREAS

Future Plan Development

At the beginning of the Comprehensive Study, there was an expectation that *system-wide master plans* would be recommended for both river basins. While the ability to develop system-wide projects exists, there is currently little stakeholder consensus for physical projects at this scale. Therefore, system-wide projects are likely to be non-structural in nature, such as additional floodplain management measures.

Because of the complex nature of the flood management system, major physical changes should at least be evaluated on a *regional* scale. The Comprehensive Plan identifies seven regions that share common physical characteristics and stakeholder concerns: the upper, middle and lower Sacramento River regions, the Feather river region, the American river region, and the upper (south) and lower (north) San Joaquin River regions. Because hydrology, hydraulics, flood management system features, and land uses tend to be unique to each of these regions, issues common to stakeholders could be more easily addressed and resolved at a regional level. It is anticipated that the Comprehensive Study's focus will shift toward regional and local evaluations.

Lastly, many entities will continue to pursue *site-specific projects* to address specific or local problems. Project development at this level can proceed as long as the Guiding Principles recommended by the Comprehensive Plan are followed, particularly the consideration of system wide effects.

CONCLUSIONS

The economic analysis for the Comprehensive Study and associated Comprehensive Plan (Interim Report 2002) is very much an ongoing process. With regard to economics, work completed to date includes (a) compilation of land use and structural inventories for 110 impact areas in both basins, including almost 200,000 parcels and 1.6 million acres of irrigated crops, and (b) HEC-FDA evaluations of existing condition expected annual damage for both basins. The HEC-FDA models, and the associated hydrologic and hydraulic models, represent one of the largest applications of these models in the country. Preliminary hydraulic and HEC-FDA modeling runs were performed for several basin-wide evaluations. The basin-wide evaluations have improved the study team's understanding of the river systems, although no specific conclusions have been reached.

Potential measures have been identified which could lead to system-wide, regional, and/or local projects. Although no economic analysis has been done for specific projects, the existing condition information and analyses described herein will serve as the basis for future economic evaluations as projects are identified for more detailed study. Future and ongoing studies, such as the Enhanced Flood Response and Emergency Preparedness Plan and the Hamilton City Flood Damage Reduction and Ecosystem Restoration Project, will follow Corps guidance (for example, ER 1105-2-100).

Because future projects will likely include both flood damage reduction and environmental restoration objectives for large geographic regions, with implementation expected to occur possibly over decades by numerous agencies, economic justification for this non-traditional study using traditional Corps methodology raises challenges. Some of these issues include the evaluation of projects on an incremental vs. a system-wide wide basis; emphasis upon

regional and other social impacts; the evaluation of ecosystem benefits; and how to equitably distribute costs among beneficiaries. Although both the Corps and the State are working together, the State may ultimately have more flexibility in conducting the economic analysis and making recommendations based on that analysis. For example, although the Corps is required to perform an "incremental" analysis for individual projects, the State may also evaluate individual projects as part of larger, regional solutions with an overall benefit/cost analysis. For these reasons, future projects recommended by the State (and local agencies) may be different from what would be recommended by a traditional Corps economic analysis. Further, projects recommended using non-traditional evaluation methods might not receive Congressional authorization if they do not follow established Federal criteria.

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