FLOOD INSURANCE STUDY

VOLUME 1 OF 5

CONTRA COSTA COUNTY, CALIFORNIA

AND INCORPORATED AREAS

Community Name	Community Number
ANTIOCH, CITY OF	060026
BRENTWOOD, CITY OF	060439
CLAYTON, CITY OF	060027
CONCORD, CITY OF	065022
DANVILLE, TOWN OF	060707
EL CERRITO, CITY OF	065027
HERCULES, CITY OF	060434
LAFAYETTE, CITY OF	065037
MARTINEZ, CITY OF	065044
MORAGA, TOWN OF	060637
OAKLEY, CITY OF	060766
ORINDA, CITY OF	060722
PINOLE, CITY OF	060032
PITTSBURG, CITY OF	060033
PLEASANT HILL, CITY OF	060034
RICHMOND, CITY OF	060035
SAN PABLO, CITY OF	060036
SAN RAMON, CITY OF	060710
WALNUT CREEK, CITY OF	065070
CONTRA COSTA COUNTY (UNINCORPORATED AREAS)	060025

REVISED
March 21, 2017

Federal Emergency Management Agency

FLOOD INSURANCE STUDY NUMBER
06013CV001C

NOTICE TO
FLOOD INSURANCE STUDY USERS

Communities participating in the National Flood Insurance Program have established repositories of flood hazard data for floodplain management and flood insurance purposes. This Flood Insurance Study (FIS) may not contain all data available within the repository. It is advisable to contact the community repository for any additional data.

Part or all of this FIS may be revised and republished at any time. In addition, part of this FIS may be revised by the Letter of Map Revision process, which does not involve republication or redistribution of the FIS. It is, therefore, the responsibility of the user to consult with community officials and to check the community repository to obtain the most current FIS components.

Initial Countywide FIS Effective Date: June 16, 2009

Revised Countywide FIS Dates: September 30, 2015
March 21, 2017

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FLOOD INSURANCE STUDY

CONTRA COSTA COUNTY, CALIFORNIA AND INCORPORATED AREAS

1.0 INTRODUCTION

1.1 Purpose of Study

This countywide Flood Insurance Study (FIS) revises and updates information on the existence and severity of flood hazards in the geographic area of Contra Costa County, California, including: the Cities of Antioch, Brentwood, Clayton, Concord, El Cerrito, Hercules, Lafayette, Martinez, Oakley, Orinda, Pinole, Pittsburg, Pleasant Hill, Richmond, San Pablo, San Ramon, Walnut Creek, the Towns of Danville and Moraga, and the unincorporated areas of Contra Costa County (hereinafter referred to collectively as Contra Costa County).

This FIS aids in the administration of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. This FIS has developed flood risk data for various areas of the county that will be used to establish actuarial flood insurance rates. This information will also be used by Contra Costa County to update existing floodplain regulations as part of the Regular Phase of the National Flood Insurance Program (NFIP), and will also be used by local and regional planners to further promote sound land use and floodplain management. Minimum floodplain management requirements for participation in the NFIP are set forth in the Code of Federal Regulations at 44 CFR, 60.3.

In some States or communities, floodplain management criteria or regulations may exist that are more restrictive or comprehensive than the minimum Federal requirements. In such cases, the more restrictive criteria take precedence and the State (or other jurisdictional agency) will be able to explain them.

1.2 Authority and Acknowledgments

The sources of authority for this FIS are the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973.

This FIS was prepared to include all jurisdictions within Contra Costa County in a countywide FIS. The authority and acknowledgments prior to the initial countywide FIS, were compiled from the previously identified FIS reports for flood prone jurisdictions within Contra Costa County and are shown below:

Antioch, City of: The hydrologic and hydraulic analyses for the original study were performed by Tudor Engineering Company, for the Federal Emergency Management Agency (FEMA), under Contract No. H-4033. The revised study on East Antioch Creek was performed by Gill and Pulver Engineers Inc. under Contract No. EMW-R-1179.

This study was completed in October 1978 and revised in October 1985.

Brentwood, City of: No FIS available.

Clayton, City of: For the original study for City of Clayton (Reference 1), hydrologic and hydraulic analyses were performed by Tudor Engineering Company for FEMA under Contract No. H-4033. This study was completed in May 1978.

Concord, City of: The hydrologic and hydraulic analyses for this study were performed by Tudor Engineering Company, for FEMA under Contract No. H-4033. This study was completed in April 1981. Hydraulic analyses for Mt. Diablo Creek downstream of Ayers Road was performed by Dames & Moore under Contract No. C-0542.

This study was revised on September 7, 2001, to incorporate detailed flood hazard information along Galindo Creek from approximately 3,025 feet (0.57 mile) downstream of Contra Costa Canal to Dam #1, which is approximately 2,840 feet upstream of Wharton Way and along Mount Diablo Creek from a point approximately 2,675 feet downstream of Bailey Road to a point approximately 35 feet downstream of Russelmann Park Road, located in the Unincorporated Areas of Contra Costa County. The hydraulic analyses for the restudy were performed for FEMA by Questa Engineering Corporation, under Contract No. EMW-93-C-4186 and were completed in October 1997. The hydrologic data utilized in the restudy were obtained from the Contra Costa County Flood Control and Water Conservation District (CCCFCWCD). The information prepared by Questa Engineering Corporation was subsequently modified by Michael Baker Jr., Inc. to conform to current FEMA standards. The modifications were completed in August 1999.

The behind levee analyses for this study were performed by URS Corporation, for FEMA, under Contract No. EMF-2003-CO-0047. This work was completed in October and November 2007.

Danville, Town of: The hydrologic and hydraulic analyses for this study were performed by Tudor Engineering Company, for FEMA, under Contract No. H-4033. This study was completed in May 1983.

This study was revised on September 7, 2001, to provide detailed flood-hazard information for Green Valley Creek from the upstream end of the Interstate 680 culvert to a point approximately 4,424 feet (0.84 mile) upstream of Stone Valley Road, located in the Unincorporated Areas of Contra Costa County, California, and along East Branch Green Valley Creek from its confluence to a point approximately 125 feet upstream of its confluence with Green Valley Creek. The hydraulic analyses for the restudy were performed for FEMA by Questa Engineering Corporation, under Contract No. EMW-93-C-4186. This work was completed in October 1997. The hydrologic data utilized in this study were obtained from the CCCFCWCD. The information prepared by Questa Engineering Corporation was subsequently modified by Michael Baker Jr., Inc. to conform to current FEMA standards. The modifications were completed in August 1999.

The hydrologic and hydraulic analyses for the third restudy were performed by Borcalli & Associates, Inc., for FEMA, under Contract No. EMF-98-CO-0082. This work was submitted to FEMA in February 2000.

El Cerrito, City of: The hydrologic and hydraulic analyses for this study were performed by the Natural Resources Conservation Service (NRCS), U.S. Department of Agriculture, for FEMA, under Inter-Agency Agreement IAA-H-9-71, Project Order No. 17. This work, which was completed in November 1971, covered all flooding sources affecting the City of El Cerrito.

Hercules, City of: The hydrologic and hydraulic analyses for this study were performed by Tudor Engineering Company, for FEMA, under Contract No. H-4033. This work, which was completed in September 1978, covered all significant flooding sources affecting the City of Hercules.

Lafayette, City of: The hydrologic and hydraulic analyses for this study were performed by Tudor Engineering Company, for FEMA, under Contract No. H-4033. This work, which was completed in October 1979, covered all significant flooding sources affecting the City of Lafayette.

This study was revised on May 20, 1996, to incorporate new detailed hydrologic and hydraulic analyses for Las Trampas Creek, affecting the Cities of Lafayette and Walnut Creek, and Contra Costa County, California. The hydrologic and hydraulic analyses for the restudy were performed by Questa Engineering Corporation. This work was completed on May 27, 1994, and the results of the analyses are represented in reports entitled "Technical Support Data Notebook, for Downtown Walnut Creek and Tributaries, Contra Costa County, California," Volume Nos. 1 and 2, and "Technical Support Data Notebook, for Downtown Walnut Creek and Tributaries, Contra Costa County, California, HEC-II Output Files," Volume Nos. 3, 4, 5, all dated May 27, 1994.

A third study was revised on December 20, 2002 to incorporate new detailed flood hazard information for Reliez Creek and Reliez Creek Overflow in the City of Lafayette. The hydrologic and hydraulic analyses for this restudy were performed by Borcalli & Associates, Inc., for FEMA, under Contract No. EMF-98-CO-0082. This work was submitted to FEMA in February 2000.

Martinez, City of: For the original study for the City of Martinez (Reference 2), the hydrologic and hydraulic analyses were performed by the U.S. Army Corps of Engineers (USACE), for FEMA, under Interagency Agreement No. IAAH871, Project Order No. 10. This work, which was completed in June 1971, covered all significant flooding sources with the exception of Franklin Creek. Approximate flood boundaries for Franklin Creek were determined in November of 1975 by Dames & Moore for FEMA under Contract No. H-3952.

Bissell and Karn, Incorporated, subcontractors to the USACE, contacted the city in connection to the original study. Map information was provided by the CCCFCWCD.

The hydraulic analyses for the restudy were performed for FEMA by Questa Engineering Corporation, under Contract No. EMW-93-C-4186 and completed in October 1997. The hydrologic data utilized in the restudy were obtained from the CCCFCWCD. The information prepared by Questa Engineering Corporation was subsequently modified by Michael Baker Jr., Inc., to conform to current FEMA standards. The modifications were completed in August 1999.

Moraga, Town of: The hydrologic and hydraulic analyses for this study were performed by Tudor Engineering Company, for FEMA, under Contract No. H-4033. This work, which was completed in May 1979, covered all significant flooding sources affecting Moraga.

Oakley, City of: The hydrologic and hydraulic analyses for this study were performed by Tudor Engineering Company, for FEMA, under Contract No. H-4033. This study was completed in November 1982, and published for Contra Costa County, California (Reference 3).

The behind levee analyses for this study were performed by URS Corporation, for FEMA, under Contract No. EMF-2003-CO-0047. This work was completed in October and November 2007.

Orinda, City of: The hydrologic and hydraulic analyses for this study were performed by Tudor Engineering Company, the study contractor, for FEMA under Contract No. H-4033.

	This study was revised on July 17, 1997. The hydraulic analyses for the restudy were prepared by Ensign & Buckley Consulting Engineers, the study contractor, for FEMA, under Contract No. EMW-90-C-9133. As directed by the FEMA Project Officer (PO), the hydrologic analyses adopted for this study were prepared by the CCCFCWCD.
Pinole, City of:	The hydrologic and hydraulic analyses for this study were performed by Tudor Engineering Company, for FEMA, under Contract No. H-4033. This work, which was completed in April 1978, covered all significant flooding sources affecting the City of Pinole.
Pittsburg, City of:	The hydrologic and hydraulic analyses for the study completed in November 1978, were performed by Tudor Engineering Company, for FEMA, under Contract No. H-4033. A study of tidal flooding on the Sacramento-San Joaquin Delta area was performed by the USACE under Interagency Agreement No. IAA-EMW-E-1153, Project Order No. 1, Amendments No. 22 and 22(a). This study was completed in November 1985.
	This study was revised on September 7, 2001, to incorporate detailed flood hazard information along Kirker Creek from approximately 80 feet downstream of East 14^{th} Street to approximately 140 feet upstream of Brush Creek Drive.
	The hydraulic analyses for the restudy were performed for FEMA by Questa Engineering Corporation, under Contract No. EMW-93-C-4186 and was completed in October 1997. The hydrologic data utilized in this study was obtained from the CCCFCWCD. The information prepared by Questa Engineering Corporation was subsequently modified by Michael Baker Jr., Inc., to conform to current FEMA standards. The modifications were completed in August 1999.
	The behind levee analyses for this study were performed by Nolte Engineering Company, for FEMA. This work was completed in June 2007.
Pleasant Hill, City of:	Approximate flood boundaries for Franklin Creek were determined in November 1975 by Dames & Moore for FEMA, under Contract No. H-3952. For the original study (Reference 4), the hydrologic and hydraulic analyses were performed by Tudor Engineering Company for FEMA under Contract No. H-4033. This work was completed in June 1981.
	The hydraulic analyses for the restudy were performed for FEMA in two phases. The hydraulic analyses along Grayson Creek and

East Fork Grayson Creek downstream of Gregory Lane were performed by Questa Engineering Corporation (Questa) under Contract No. EMW93-C-4186 and completed in October 1997. The hydraulic analysis along Murderers Creek and East Fork Grayson Creek upstream of Gregory Lane was performed by Borcalli & Associates, Inc. (B&A) under Contract No. EMF-96-CO-0097 and completed in July 1999. The hydrologic data that Questa used in this restudy were obtained from the CCCFCWCD. The hydrologic data that B&A used in this restudy were based upon a combination of U.S. Geological Survey (USGS) regression equations (Reference 5) and the hydrology developed by the CCCFCWCD. This analysis was revised by FEMA in December 2002, based on information and comments provided by the City of Pleasant Hill.

Richmond, City of: The hydrologic and hydraulic analyses in this study represent a revision of the original analyses by the USACE, San Francisco District, for FEMA, under Inter-Agency Agreement No. IAA-H-2-73, Project Order No. 4. The updated study was prepared by Dewberry, Nealon and Davis under agreement with FEMA. This work, which was completed in April 1975, covered all significant flooding sources in the City of Richmond.

This study was revised on November 17, 1993 to include the detailed study for 0.7 miles of Rheem Creek from its mouth to the Burlington Northern Santa Fe Railroad. The revised study was prepared by the USACE, San Francisco District, the study contractor, for FEMA under Interagency Agreement No. EMW-89-E-2994, Project Order No. 8A, and was completed in March 1992.

The behind levee analyses for this study were performed by Nolte Engineering Company, for FEMA. This work was completed in June 2007.

San Pablo, City of: The hydrologic and hydraulic analyses for the original study were performed by the USACE, San Francisco District, under Interagency Agreement No. (IAA)-H-2-73, Project Order No. 4.

Hydrologic and hydraulic analyses for the Rheem Creek restudy were performed by the USACE, San Francisco District, for FEMA, under Interagency Agreement No. EMW-89-E-2994, Project Order No. 8A. This study was completed in March 1992.

The hydraulic analyses for this revision of San Pablo Creek and Wildcat Creek were performed for FEMA by Questa Engineering Corporation, the Study Contractor (SC), under Contract No. EMW-93-C-4186. Hydrologic analyses were taken from a study prepared for the USACE, Sacramento District, by Water Engineering and Technology, Inc. (WET) (Reference 6). During the appeal period, the City of San Pablo submitted hydraulic analyses, developed by WRECO, for San Pablo and Wildcat Creeks (Reference 7). Information obtained from these analyses were modified by FEMA to conform to current standards and were used in the preparation of this FIS and the FIRM.

San Ramon, City of: The hydrologic and hydraulic analyses for the original study were performed by Tudor Engineering Company, as reported in the Flood Insurance Study for Contra Costa County, California (Reference 8).

The hydrologic and hydraulic analyses for the first revision for this study were performed by the USACE, San Francisco District.

The Limited Map Maintenance Program (LMMP) revision for this study was performed by the USACE under Interagency Agreement No. EMW-87-E2549, Project Order No. 8, dated March 19, 1987, and FEMA's Tasking Letter to the USACE dated August 8, 1987.

Walnut Creek, City of: The hydrologic and hydraulic analyses for this study were performed by Tudor Engineering Company, for FEMA, under Contract No. H-4033. This study was completed in November 1982.

This study was revised on May 20, 1996, to incorporate new detailed hydrologic and hydraulic analyses for Las Trampas Creek, San Ramon Creek, San Ramon Bypass, Sans Crainte Creek, Tice Creek, and Walnut Creek, affecting the Cities of Lafayette and Walnut Creek, and Contra Costa County, California. The analyses were performed by Questa Engineering Corporation. This work was completed on May 27, 1994, and the results of the analyses are represented in reports entitled "Technical Support Data Notebook, for Downtown Walnut Creek and Tributaries, Contra Costa County, California, Volume Nos. 1 and 2," and "Technical Support Data Notebook, for Downtown Walnut Creek and Tributaries, Contra Costa County, California, HEC-II Output Files, Volume Nos. 3, 4, and 5," all dated May 27, 1994.

A third study was revised on October 4, 2002, to incorporate new detailed flood hazard information for East Fork Grayson Creek and Eccleston Avenue Tributary within the City of Walnut Creek. The hydrologic and hydraulic analyses for this restudy were performed by Borcalli & Associates, Inc., for FEMA under Contract No. EMF-96-CO-0097. This work was completed in July 1999.

Contra Costa County: (Unincorporated Areas)

The hydrologic and hydraulic analyses for this study were performed by Tudor Engineering Company, for FEMA, under Contract No. H-4033. This study was completed in November 1982.

Additional information for coastal areas was taken from the USACE study of Sacramento-San Joaquin Delta and Mokelumne River, completed in November 1985 (Reference 9).

This study was revised on May 20, 1996, to incorporate new detailed hydrologic and hydraulic analyses for Las Trampas Creek, San Ramon Creek, San Ramon Creek - Overflow, San Ramon Creek Bypass Channel, Sans Crainte Creek, Sans Crainte Tributary A, and Tice Creek, affecting the Cities of Lafayette and Walnut Creek, and Contra Costa County, California. The analyses were performed by Questa Engineering Corporation. This work was completed on May 27, 1994, and the results of the analyses are represented in reports entitled "Technical Support Data Notebook, for Downtown Walnut Creek and Tributaries, Contra Costa County, California, Volume Nos. 1 and 2," and "Technical Support Data Notebook, for Downtown Walnut Creek and Tributaries, Contra Costa County, California, HEC-II Output Files, Volume Nos. 3, 4, and 5," all dated May 27, 1994.

A third study was revised on September 7, 2001, to incorporate detailed flood hazard. The hydrologic analyses for San Pablo Creek and Wildcat Creek were taken from a study that was prepared for the USACE, Sacramento District, by Water Engineering and Technology, Inc. (WET) (Reference 6). The hydrologic data utilized for the remaining streams were obtained from the CCCFCWCD. The hydraulic analyses were performed for FEMA by Questa Engineering Corporation under Contract No. EMW-93-C-4186 and completed in October 1997. The information prepared by Questa Engineering Corporation was subsequently modified by Michael Baker Jr., Inc. to conform to current FEMA standards. The modifications were completed in August 1999.

A fourth study was revised on December 2, 2003, to incorporate new detailed flood hazard information for Murderers Creek within the unincorporated areas of Contra Costa County. The hydrologic and hydraulic analyses for this restudy were performed by Borcalli & Associates, Inc., for FEMA, under Contract No. EMF-96-CO-0097. This work was completed in July 1999.

The behind levee analyses for this study were performed by Nolte Engineering Company, for FEMA. This work was completed in June 2007.

The behind levee analyses for this study were also performed by URS Corporation, for FEMA, under Contract No. EMF-2003-CO-0047. This work was completed in October and November 2007.

MAP IX-Mainland was contracted; contract number EMF-2003-CO-0047, in February of 2005 by FEMA to create a Contra Costa Countywide FIS and DFIRM.

Base map information shown on this FIRM was provided in digital format by the USDA National Agriculture Imagery Program (NAIP). This information was photogrammetrically compiled at a scale of 1:24,000 from aerial photography dated 2005.

The projection used in the preparation of this map was Universal Transverse Mercator (UTM) Zone 10N. The horizontal datum was NAD83, GRS80 spheroid. Differences in datum, spheroid, projection or UTM zone used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differenced do not affect the accuracy of information shown on the FIRM.

1.3 Coordination

Consultation Coordination Officer's (CCO) meetings may be held for each jurisdiction in this countywide FIS. An initial CCO meeting is held typically with representatives of FEMA, the community, and the study contractor to explain the nature and purpose of a FIS, and to identify the streams to be studied by detailed methods. A final CCO meeting is held typically with representatives of FEMA, the community, and the study contractor to review the results of the study.

The dates of the initial and final CCO meetings held for Contra Costa County and the incorporated communities within its boundaries are shown in Table 1, "Initial and Final CCO Meetings."

Table 1: Initial and Final CCO Meetings

Community Name	Initial CCO Date	Final CCO Date
City of Antioch	May 13, 1976	April 23,1979
City of Clayton	May 13, 1976	October 4, 1978
City of Concord	February 22, 1977	February 5, 1981
	January 8, 1993	September 26, 2000
Town of Danville	May 14, 1976	February 14, 1983
	January 8, 1993	September 27, 2000
City of El Cerrito	*	July 7, 1976

Table 1: Initial and Final CCO Meetings, continued

Community Name	Initial CCO Date	Final CCO Date
City of Hercules	May 12, 1976	February 20, 1979
City of Lafayette	May 12, 1976	May 24, 1979
	January 8, 1993	*
	May 6, 1998	February 12, 2002
City of Martinez	*	June 16, 1977
Town of Moraga	May 12, 1976	June 25, 1980
City of Oakley	May 14, 1976	February 14, 1983
City of Orinda	May 14, 1976	February 14, 1983
	March 9, 1992	May 16, 1994
City of Pinole	May 12, 1976	September 5, 1978
City of Pittsburg	May 13, 1976	April 23, 1979
	January 8, 1993	September 28, 2000
City of Pleasant Hill	February 10, 1977	November 9, 1982
City of Richmond	*	March 16, 1978
	March 22, 1990	January 13, 1993
City of San Pablo	*	*
City of San Ramon	May 14, 1976	February 14, 1983
City of Walnut Creek	February 22, 1977	June 23, 1982
	January 8, 1993	*
	May 6, 1998	April 30, 2001
Unincorporated Areas	May 14, 1976	February 14, 1983
(Contra Costa County)	January 8, 1993	September 19, 2000
	May 6, 1998	April 30, 2001
**Data not available*		

For the initial countywide study, a CCO meeting took place on February 13, 2008, and was attended by representatives of FEMA, the community, and the study contractor.

For the September 30, 2015, revision, the CCO meeting took place on July 14, 2014, and was attended by representatives for FEMA, the community, and the study contractor.

2.0 AREA STUDIED

2.1 Scope of Study

This FIS covers the geographic area of Contra Costa County, California, including the incorporated communities listed in Section 1.1. The areas studied by detailed methods were selected with priority given to all known flood hazards.

All or portions of the flooding sources listed in Table 2, "Flooding Sources Studied by Detailed Methods," were studied by detailed methods. Limits of detailed study are indicated on the Flood Profiles (Exhibit 1) and on the FIRM (Published Separately).

Table 2: Flooding Sources Studied by Detailed Methods

Along Giant Road from Standard Oil to Rheem Creek	Miranda Creek
	Mitchell Creek
Appian Creek	Moraga Creek
Arroyo Del Hambra Creek	Mount Diablo Creek
Brookside Road Tributary	Mount Diablo Split Flow
Carquinez Straight	Murderers Creek
Cascade Creek	North Branch Reliez Creek
Cerrito Creek	North Branch Stone Valley Creek
Clayton Valley Drain	Orinda Village Overflow
Corliss Drive Tributary	Overhill Creek
Deer Creek	Overland Cross Section
Ditch No. 2	Pacheco Creek
Donner Creek	Payton Slough
Dutch Slough	Pine Creek
East Antioch Creek	Pinole Creek
East Branch Green Valley Creek	Refugio Creek
East Branch Homestead Creek	Reliez Creek
East Branch Refugio Creek	Rheem Creek Rodeo Creek
East Fork Grayson Creek	Sand Creek
Eccleston Avenue Tributary	San Francisco Bay
Farm Bureau Road Drain	San Pablo Bay
Galindo Creek	San Pablo Creek

Table 2: Flooding Sources Studied by Detailed Methods, continued

Garrity Creek	San Ramon Creek
Grayson Creek	San Ramon Creek Overflow
Green Valley Creek	Sans Crainte Creek
Grizzly Creek	Sans Crainte Creek Tributary A
Happy Valley Creek	Shore Acres Creek
Hidden Valley Creek	South Branch Moraga Creek
Hillcrest Branch East Antioch Creek	South San Ramon Creek (overbank flooding)
Homestead Creek	South San Ramon Creek
Ivy Drive Tributary	St. Marys Road Tributary
Jonas Hill Creek	Stone Valley Creek
Kirker Creek	Suisun Bay
Lafayette Creek	Sycamore Creek
Laguna Creek	Tice Creek
Larch Creek	Tice Creek Overflow
Las Trampas Creek	Walnut Creek
Lauterwasser Creek	West Antioch Creek
Lawlor Creek	West Branch Alamo Creek
Line A, DA-40	West Branch East Antioch Creek
Los Medanos Wasteway	West Branch Refugio Creek
Mangini Creek	Wildcat Creek
Markley Creek	Willow Creek
Marsh Creek	
Middle Branch West Antioch Creek	

All or portions of numerous flooding sources in the county were studied by approximate methods. Approximate analyses were used to study those areas having a low development potential or minimal flood hazards. The scope and methods of study were proposed to, and agreed upon by, FEMA and the communities. All or portions of the flooding sources listed in Table 3, “Flooding Sources Studied by Approximate Methods,” were studied by approximate methods.

Table 3: Flooding Sources Studied by Approximate Methods

Alamo Creek	Lake Cascade
Arroyo del Cerro Creek	Las Trampas Creek
Arroyo del Hambra Creek	Little Pine Creek
Bolinger Creek	Marsh Creek
Briones Reservoir	Mitchell Creek
Brushy Creek	North Branch Reliez Creek
Buckhorn Creek	Pacheco Creek
Carquinez Straight	Pine Creek
Cerrito Creek	Pinole Creek
Clifton Court Forebay	Refugio Creek
Deer Creek	San Catanio Creek
East Antioch Creek	Sand Creek
East Branch Green Valley Creek	San Leandro Creek
Franklin Creek	San Leandro Reservoir
Garrity Creek	San Pablo Creek
Grayson Creek	San Pablo Reservoir
Green Valley Creek	San Ramon Creek
Hastings Slough	Sycamore Creek
Hilltop Lake	Tassajara Creek
Horse Valley Creek	Tice Creek
Indian Creek	Unnamed Creek
Ivy Drive Tributary	Walnut Creek
Kellogg Creek	Wildcat Creek
Lafayette Reservoir	West Branch Alamo Creek

This countywide FIS also incorporates the determinations of letters issued by FEMA resulting in map changes (Letter of Map Revision – LOMR), as shown in Table 4, "Letters of Map Change." LOMR case 09-09-0916P, involving Lindsey Basin and Lindsey Channel, was superseded by a new, approximate-method flood study. LOMR case 10-09-3361P, involving San Pablo Creek and Wildcat Creek, was superseded by redelineation of the associated flood hazard areas on updated topographic data.

Table 4: Letters of Map Change

Community	Case Number	Project Identifier	Effective Date	Type
Contra Costa County	09-09-1704P	Port Costa Area Map Update LOMR	June 17, 2009	LOMR
Contra Costa County	09-09-2343P	Shore Acres Creek Map Update LOMR	August 31, 2009	LOMR
Contra Costa County	09-09-2712P	Belmont Terrace	September 22, 2009	LOMR
City of Pittsburg	10-09-0568P	River Run Subdivision	March 15, 2010	LOMR
City of Oakley	10-09-3624P	Summer Lake	December 24, 2010	LOMR
City of Hercules	11-09-0315P	Refugio Valley SFHA Redelineation	January 21, 2011	LOMR
City of Pittsburg	12-09-2983P	Harbor Lights Subdivision Levee Certification	May 6, 2013	LOMR

For this countywide FIS revision, components from LOMR case 09-09-1576P, involving Farm Bureau Road Drain, and case 10-09-3220P, involving San Ramon Creek, were incorporated to be consistent with their respective determinations. However, these LOMRs have not been incorporated into the FIRM exhibit and remain independently effective.

2.2 Community Description

Contra Costa County is located in northern California. It is bounded to the west by the San Francisco Bay, to the northwest by the San Pablo Bay, to the north by the Suisun Bay and San Joaquin River, to the east by San Joaquin County, and to the south and west by Alameda County.

Contra Costa County was first explored in the latter part of the 18th Century. Several subsequent expeditions ensued, and the first land grants in the area were applied for in 1823. Martinez and Pittsburg, the first towns in the area, were established in 1849. In 1850, California became a state, with Contra Costa County as one of the original 27 counties. The county began to grow, but was divided in 1853. The southwest portion became Alameda County. The discovery of coal on Mt. Diablo, the expansion of roads through the county, and the completion of the transcontinental railroad in the latter part of the 19th Century all contributed to the growth of Contra Costa County (Reference 10).

The growth of the county was slow until 1940, at which time the population was 100,000. Between 1940 and 1950, the county's population tripled, with exceptional growth in the Richmond area. After 1950, the population concentration began shifting to the central part of the county, with rapid growth in the Cities of Concord, Pleasant Hill, Lafayette and Walnut Creek (Reference 11).

The topography of the county varies significantly. Bounded on the west by the San Francisco Bay depression and on the east by the broad expanse of the Sacramento-San Joaquin Delta, most of the county consists of a series of northwest-trending ridges and intermountain valleys of the Coast Range. Elevations vary from 20 feet below sea level on the levee-protected delta islands to over 3,800 feet on Mt. Diablo. Most of the mountain valleys are youthful and V-shaped. The foothills are rolling, with gentle to very steep faces; the larger valleys are filled with broad, flat alluvial fans. Principal drainages flow northerly. The undeveloped areas are vegetated principally with oak woodland, pasture grasses, and chaparral.

Terrain in the delta area is very flat with relief practically indiscernible. Much of the land surface lies well below sea level. In the flood-generating regions of the Sacramento and San Joaquin River basins, topography varies from gently rolling foothills to precipitous canyons and rugged mountains rising to more than 13,000 feet above sea level.

Agriculture in Contra Costa County is highly diversified. In the early 1900s, a large portion of the grain cropland was converted to fruit and nut orchards, and vineyards. Vegetable crops were introduced in the 1920s and 1930s, thus adding to the diversity of agriculture in the county (Reference 10).

Since the 1950s, the amount of agricultural land has declined in Contra Costa County. This is primarily due to the suburban development of the Cities of Concord, Pleasant Hill, and Walnut Creek. Although prime agricultural acreage has been greatly reduced, agricultural production in the county has not suffered proportionately as a result of increased productivity due to new farming techniques (Reference 11).

Most of Contra Costa County has a Mediterranean climate, typified by dry summers and moderately rainy winters. Average monthly temperatures vary from 46°F in January to

76°F in August. The northwestern part of the county, however, has a marine-type climate, with minimal seasonal temperature changes. Average precipitation in the county ranges from 12.5 inches in the eastern part of the county to more than 30 inches on Mt. Diablo (Reference 11).

In general, Contra Costa County has wet mild winters with hot dry summers. In the winter, storms coming off the Pacific Ocean are responsible for approximately 95 percent of the annual precipitation in the County. Summer thunderstorms are usually very weak. The winter storms are usually large and typically reach several miles in height and several hundred miles in diameter. Therefore, the winter storm precipitation usually covers the entire County of Contra Costa.

2.3 Principal Flood Problems

Flooding in Contra Costa County is predominantly confined within traditional riverine valleys. Locally, natural or manmade levees separate channels from flood plains and cause independent overland flow paths. Occasionally, railroad, highway, or canal embankments form barriers, resulting in ponding or diversion of the flow. The delta area has been reclaimed by about 1,100 miles of levees along natural and manmade waterways that segregate it into about 120 tracts locally known as islands. The entire region of approximately 700,000 acres is under the influence of the tides and a large part of the land surface is lower than the water on the opposite side of the levees. Many of the islands are 15 to 25 feet below sea level due to the subsidence of the peat land structure. Flooding of the delta islands has usually resulted from structural failure of the levees prior to overtopping (Reference 12).

Major floods occurred in February 1940, December 1955, April 1958, and January 1963. The peak discharge measured at a number of stream gaging stations in the county (Reference 13), and the estimated recurrence intervals of those discharges (if available) are listed in Table 5, "Historic Floods."

The flood of December 1955, with an estimated recurrence interval of 22 years, came to be known as "The Big Flood." Flood conditions created by heavy rains were aggravated by high tides. The damage in Contra Costa County was extensive, with an estimated loss of $1.25 million (1955 dollars) to private dwellings. Approximately 460 families were evacuated from Byron, Brentwood, Knightson, Tree Haven, Fair Oaks, Meadow Homes, Sherman Acres, Gregory Gardens (now part of the City of Pleasant Hill), and the City of Walnut Creek. The delta area of Contra Costa County suffered permanent damage to a sizeable amount of agricultural land (Reference 14). Delta flooding is a continuing problem and has a long history. Since construction of levees started in the early 1860s, every island has been flooded at least once due to levee overtopping or failure. Prior to 1950 most of the failures were due to levee overtopping.

However, since the construction of many upstream dams, the flood factor has been reduced and now the major cause of flooding is levee instability. Approximately 110 levee failures have occurred since 1900, almost 45 since 1930, approximately 25 since 1950, and about 12 since 1980.

Little definitive data are available for specific flood events. However, records show that during the period from 1850 to the early 1900s, 13 of the many floods that occurred were outstanding events (1850, 1852, 1861-62, 1871, 1875, 1878, 1879, 1881, 1902, 1904, 1906, 1907, and 1909). Of these 13 floods, those that occurred in 1878, 1881, 1904, 1907, and 1909 were the most severe. Large portions of the delta area were inundated and there was widespread and extensive damage. The most recent major flood events were those that occurred in 1950, 1955, 1964-65, 1969, 1972, 1980, 1982, and 1983.

The 1950 and 1955 floods were outstanding in peak outflows through the delta area and several islands were flooded. The 1955 floodflow inundated almost 38,000 acres, more than doubling the flooded acreage of 1950 (about 18,000), and caused about $3.3 million in damages, compared to about $1.2 million in 1950. In December 1964 and January 1965, the coincidental occurrence of very high tides and heavy inflow resulted in unusually high stages on all delta area waterways. Concurrent strong onshore winds generated high waves that created very perilous conditions for many islands. Several hundred acres were flooded, and damages, mainly floodlighting and repair of levees and levee roads, were a little less than $1 million. In January and February 1969, high tides and adverse wave action in the delta area combined with large river inflow and rain-soaked levees to cause the flooding of several islands and the endangerment of many other islands. Approximately 11,400 acres were inundated and flood damages amounted to approximately $9.2 million.

In mid-January 1980, severe rainstorms over central California precipitated high river outflow through the delta area which, coinciding with gale force winds over the delta area and high tides, resulted in the levee failure and flooding of two tracts (placing approximately 9,600 acres under water). Continued high inflow to the delta area and wind-generated waves increased erosion on all delta-area levees, necessitating intensive floodlighting and the temporary curtailment of boat traffic.

City of Antioch

Shallow flooding occurs often in Antioch at a few locations. When culvert capacity has been exceeded, the areas north of the Union Pacific Railroad and north of West 10th Street on West Antioch Creek flood. Because of inadequate culvert capacity, water backs up behind culverts at Contra Loma Boulevard and at L Street on West Antioch Creek. Flooding of the low-lying areas adjacent to Lake Alhambra on East Antioch Creek is also a problem. At Lake Alhambra, flooding is aggravated by the North Lake Drive bridge, located at the outlet of the lake, which, when combined with high tides, prevents the flow from draining out of the lake. The undersized culvert on Markley Creek at the Union Pacific Railroad causes the 1-percent annual chance flood to overtop the railroad embankment, but most of the flow is contained in the channel upstream of the culvert. The culvert on West Antioch Creek at the Union Pacific Railroad causes the flow to be diverted along a low area, parallel to the railroad, to L Street.

There are no stream gages in or around the City of Antioch; therefore, there are no records of past flood events.

The major floods in the adjacent basin of Marsh Creek occurred in December 1955 and January 1963 with flows of 3,800 cubic feet per second (cfs) and 3,880 cfs, respectively, both having an estimated recurrence interval of 15 years. Flooding in Antioch during these storms was limited to local drainage problems and shallow flooding of undeveloped flatlands.

City of Brentwood

There are no known principal flood problems within the City of Brentwood.

City of Clayton

The sources of flooding along Mount Diablo Creek and Mitchell Creek are primarily attributed to inadequate bridge crossings. Donner Creek generally has adequately sized culverts and bridges. In the lower portion of Mount Diablo Creek overbank flooding occurs between Bailey Road and Concord Boulevard due to inadequate channel capacity. At the Concord Boulevard Bridge crossing flow is lost to left overbank flooding down Concord Boulevard due to inadequate capacity at this crossing. At Ayers Road, located in the City of Concord, California, water spills out of the channel onto the left floodplain and flows to Heather Road, which eventually discharges to Galindo Creek. Upstream of Kirker Pass Road the development of a large supermarket and channel widening have altered the floodplain. Mount Diablo Creek does not have the capacity to accommodate the 1-percent annual chance floodflow from Kirker Pass Road to approximately 1,400 feet upstream of Lydia Lane.

Major flood affecting the area occurred in 1938, 1952, 1955, 1963, 1982, 1983, 1986, 1992, 1996 and 1998. The 1955 and 1963 floods both had an estimated recurrence interval of 25 years.

City of Concord

The flooding in the Concord area is the result of general rainstorm runoff and independent flows, which have overtopped the channel banks or levees and departed from the channel. The recent major flood-producing storms occurred in December 1952, December 1955, April 1958, October 1962, and February 1963. The estimated average recurrence interval of the floods is 10 years for the December 1955 flood, 30 years for the April 1958 flood, and 8 years for the October 1962 flood.

During the December 1955 flood, the Meadow Homes area in Concord was flooded severely with several hundred homes affected. Police and firemen used boats to evacuate some of the residents.

On April 3, 1958, the Contra Costa Gazette reported that a bridge on Sunshine Drive in Concord had buckled from floodwater. The Walnut Kernel on the same date reported the overflow of Pine Creek and the evacuation of approximately 400 families from the Meadow Homes area. On October 14, 1962, the Walnut Kernel reported the evacuation of 30 families from the Meadow Homes area when Pine Creek went over its banks. On

November 11, 1962, the Contra Costa Times reported that a total of 83 homes were flooded on October 12 and 13, 1962.

Areas of the city which were damaged by past floods include the area near the confluence of Pine Creek and Galindo Creek from Monument Boulevard to the confluence with Walnut Creek; the area between Mt. Diablo Creek near Ayers Road and Galindo Creek; and local flooding along Pine Creek, Galindo Creek, Ditch No. 2, Farm Bureau Road Drain, and Mt. Diablo Creek.

The flooding that occurs on Galindo Creek is caused by lack of channel capacity and undersized or poorly maintained culverts and bridge crossings. The Galindo Creek watershed has undergone some urbanization in the last decade but few channel modifications have been completed. In numerous instances even routine desiltation at culverts has been ignored. Residential encroachments and lack of adequate County right-of-way prohibit channel improvements at this time.

The sources of flooding along Mount Diablo Creek are primarily attributed to inadequate bridge crossings. In the lower portion of Mount Diablo Creek overbank flooding occurs between Bailey Road and Concord Boulevard due to inadequate channel capacity. At the Concord Boulevard Bridge crossing flow is lost to left overbank flooding down Concord Boulevard due to inadequate capacity at this crossing. At Ayers Road water spills out of the channel onto the left floodplain and flows to Heather Road, which eventually discharges to Galindo Creek. Upstream of Kirker Pass Road, the development of a large supermarket and channel widening has altered the floodplain. Mount Diablo Creek does not have the capacity to accommodate the 1- percent annual chance floodflow from Kirker Pass Road to approximately 1,400 feet upstream of Lydia Lane.

Town of Danville

The flooding that occurs on Green Valley Creek is caused by lack of channel capacity and undersized, or poorly maintained culverts and bridge crossings.

Flooding in Danville is caused primarily by winter rains.

City of El Cerrito

Flooding in the study area results mainly from inadequate capacity of the outlet structures, or in some cases, debris restricting flows on Cerrito Creek.

City of Hercules

There is a history of frequent flooding along the lower portions of Pinole and Refugio Creeks. In the Pinole Creek basin, the East Bay Municipal Utility District has operated a stream gage since 1939. The gage is located 4.5 miles upstream of San Pablo Bay.

The flooding along Pinole Creek was greatly reduced by the construction of a trapezoidal channel by the USACE in 1966 (Reference 14). The flooding along lower Refugio Creek is due to inadequate channel capacity. Past flooding has been very shallow, and damage has been minimal. Except for the fertilizer plant, the area is undeveloped, although the general plan calls for residential units to be built along the creek in the future. Flooding in this area is aggravated by high tides occurring concurrently with high flows.

Hydraulic analysis also indicates a potential for local flooding at some of the culverts under Sycamore and Refugio Valley Roads. South of Sycamore Road, the flow tends to pond, flooding a future park area that is designated as a flow-retaining basin. At the culvert where Refugio Creek first goes under Refugio Valley Road, the 1-percent annual chance floodflow reaches the top of the embankment and approximately 60 cubic feet per second (cfs) flow down Refugio Valley Road before reentering the channel at A Street.

City of Lafayette

Flooding in Lafayette is caused primarily by winter rains. Severe flooding occurred in 1955, 1958, and 1963. These floods have an estimated return interval of 20 to 30 years. The greatest flood damage in Lafayette resulted from the 1958 flood, when 42.8 inches of rainfall were recorded during an 8-day period, in March and April.

Areas of the city severely damaged by floods in the past include land adjacent to Happy Valley Creek, Lafayette Creek, and Jonas Hill Creek. Lesser flood damage has occurred along several of the small streams, particularly along tributaries to Happy Valley Creek and Lafayette Creek.

Most of the 1-percent annual chance floodflows are contained within the channels of the streams. Overflow, mostly in the form of sheet flow, will occur along roads: and in some overbank areas due to inadequate culvert capacities along Happy Valley, Hidden Valley, Lafayette, and Grizzly Creeks.

City of Martinez

The flooding that occurs on Line A, DA-40 is a result of inadequate capacity in the 10-foot diameter storm drain for peak flows upstream of Howe Road, with subsequent overland flow occurring along the same alignment as the storm drain during a 1-percent annual chance storm event resulting in depths of flow of less than one foot. The study reach of Line A, DA-40 consists of an existing 10- foot diameter storm drain extending from the upstream limits of the study area downstream to Howe Road. The storm drain alignment follows several roads and crosses under the backyards of several houses in the subdivision. For the remainder of the study area, Line A, DA-40 consists of a grass-lined trapezoidal shaped open channel. The open channel then flows into a long culvert underneath the Shell Oil Refinery, eventually discharging into tidal wetlands.

There are two major flood problems in the study reach of Arroyo del Hambra Creek: (1) lack of channel and bridge capacity in the lower reach (from Muir Station Road to Tahoe Drive); and, (2) the Alhambra Avenue Culvert. In the lower sections, flow leaves the channel over both banks. Flow lost over the right bank eventually returns downstream near State Highway 4 where it re-enters at a long culvert. Flow that leaves the left bank moves into a depression area to the west. Flows accumulate in this depression, causing shallow flooding. The second area of flooding occurs upstream of the Alhambra Avenue crossing. Lack of culvert capacity and an old hydraulic structure immediately upstream of the culvert cause backwater effects to spill from the channel. Water spills at the culvert headwall causing flow to move both east and west along Alhambra Avenue. The old hydraulic structure further compounds the problem, increasing the backwater problem and causing shallow flooding to the west.

Town of Moraga

Flood problems in Moraga are limited to ponding behind culverts and other local drainage problems resulting from rainfall. Until recently, Moraga was largely undeveloped, therefore; any flooding that did occur caused little or no damage and went largely unnoticed. The largest floods in the adjacent basin of San Ramon Creek occurred in December 1955 and in January 1963. During those periods, there were no reports of flooding in the developed areas of Moraga. Both storms have an estimated recurrence interval of 25 years.

Hydraulic analysis indicates flooding potential at several locations in Moraga. Flooding is limited to shallow flows at road culverts, where the waters cross the road and then reenter the channel. This shallow flooding occurs on Laguna Creek at Campolindo Drive and Moraga Road, on St. Marys Creek at Moraga Road, on Corliss Creek at Corliss Drive, and on Larch Creek at Larch Avenue. Laguna Creek, at the upper end of the culvert under Rheem Boulevard, causes flooding in several old homes on the creek banks.

City of Oakley

Flooding in Contra Costa County is predominantly confined within traditional riverine valleys. Locally, natural or manmade levees separate channels from flood plains and cause independent overland flow paths. Occasionally, railroad, highway, or canal embankments form barriers, resulting in ponding or diversion of the flow. The delta area has been reclaimed by about 1,100 miles of levees along natural and manmade waterways that segregate it into about 120 tracts locally known as islands. The entire region of approximately 700,000 acres is under the influence of the tides and a large part of the land surface is lower than the water on the opposite side of the levees. Many of the islands are 15 to 25 feet below sea level due to the subsidence of the peat land structure. Flooding of the delta islands has usually resulted from structural failure of the levees prior to overtopping (Reference 12). The northern portion of the City Oakley is subject to delta flooding via the San Joaquin River.

City of Orinda

The principal flooding problem in Orinda is along San Pablo Creek at the Orinda Village Shopping Center. At this location, the creek has been replaced by a concrete box culvert with inadequate capacity to convey 1-percent annual chance floodflow. As a result, shallow flooding (between 1 and 3 feet) occurs throughout the shopping center and adjacent roads.

The reach of Lauterwasser Creek near its confluence with San Pablo Creek overflows the banks of the creek between Camino Lenado and Miner Road. There are residential structures within this reach that can be affected by this flooding.

<u>City of Pinole</u>

Past flooding in the City of Pinole has been limited to the area between the upper Tennent Avenue Bridge and San Pablo Bay. When the flow exceeded the hydraulic capacity of the San Pablo Street Bridge, water backed up and flooded the downtown area. However, this problem has been greatly reduced by recent channel improvements.

Flooding also reportedly occurred in this area in 1907, 1916, 1922, and 1937.

The worst and most recent flood occurred in 1958, having a computed frequency of 50 years and an estimated discharge of 1660 cubic feet per second.

Flooding in the lower basin, north of the Burlington Northern Santa Fe Railway tracks, is aggravated when high tides occur simultaneously with high stream flows.

Flood damage has been limited to water damage incurred to structures and property through the deposition of waterborne silt and mud. A major problem along Pinole Creek has been the partial blockage of bridges and culverts with waterborne debris, particularly at the Burlington Northern Santa Fe Railway and Union Pacific Railroad trestles. This problem is minimized by a yearly maintenance program of the CCCFCWCD and by local teams who keep debris moving through the problem structures during periods of high water.

Local flooding due to inadequate drainage at Calais Drive and in other areas is a problem, but is not evaluated in this study.

<u>City of Pittsburg</u>

Due to the low-lying tidal nature and low elevations of the Delta area (25 feet below sea level in the central part to 20 feet above sea level on the periphery), the entire region must be considered to be in a floodplain. Flood conditions in the Delta are influenced by Pacific Ocean tides, high flood outflow from tributary streams, and strong onshore winds. A single island or a group of, islands may flood when the levees protecting them are overtopped or fail as a result of the separate or coincidental occurrence of higher high tides and high stream outflow through the Delta.

The Delta area is at the juncture of the two major drainage systems in Northern California - the Sacramento and San Joaquin Rivers. General rain floods emanating from these two basins can occur anytime during the period from November through April. This type of flood results from prolonged heavy rainfall over tributary areas and is characterized by high peak flows of moderate duration and by a large volume of runoff. Flooding is more severe when antecedent rainfall has resulted in saturated ground conditions, when the ground in tributary areas is frozen and infiltration is minimal, or when rain on snow in the high elevations adds snowmelt to rain flood runoff.

Snowmelt floods on the Sacramento and San Joaquin Rivers and their higher elevation tributaries can be expected to occur during the period from April through June. Although snowmelt flooding is of much larger volume and longer duration than flooding from rain, it does not have the high peak flows characteristic of floods from rain. Snowmelt flood runoff is sometimes augmented by late spring rains on the snowfields or lower elevation tributary watersheds.

Cloudburst storms lasting as long as 3 hours can occur over either the Delta area or the tributary drainage areas anytime from late spring to early fall, and may occur within a general rainstorm. Cloudbursts are high-intensity storms that can produce floods characterized by high peak flows, short duration of floodflow, and small volume of runoff. However, cloudburst storms are usually small in area extent and could not affect floodflow or flood stage in the Delta area.

The lower reaches of the Sacramento and San Joaquin Rivers and the entire Delta area are under the influence of the tides. The most severe flood conditions in the Delta would result when very high tides and large volume of stream outflow occur coincidentally, and strong onshore winds generate wave action. It should be noted that precipitation over the Delta does not materially affect local flood conditions.

Only minor reports of past flooding in Pittsburg were found, however there has been no major flooding in this region of Contra Costa County in the recent past. The February 1986 flood caused some erosion and damage to homes along Kirker Creek. The storms of 1955 and 1963 produced minor flooding in the adjacent city of Antioch and flood peaks equal to an approximate 15-year recurrence in the Marsh Creek basin, located 10 miles south of Pittsburg. All riverine flooding is caused by rainfall, with minor flooding in tidal areas.

Culverts throughout the Kirker Creek study reach are undersized and/or clogged with sediment. These structures are the major cause of overbank flooding. In some cases, especially under State Highway 4, flooding occurs during storms of less than a 10-year intensity and causes major disruptions and damage in the community,

Channel improvements have been made at four specific areas along Kirker Creek. These improvements have reduced the extent of the 1-percent annual chance floodplain in some areas. Starting from downstream to upstream, the improvements are: (1) installation of the El Pueblo culvert at El Pueblo Avenue; (2) removal of a 60-inch concrete culvert which was located approximately 430 feet downstream of the Embud Pipeline crossing and bridge; (3) additional fill and a second culvert at Yosemite Drive; and (4) new culverts and drop structures which have been placed between Buchanan Road and Brush Creek Drive. The installation of the El Pueblo culvert has eliminated flooding at El Pueblo Avenue and along Carpino Avenue in the lower reach. Removal of the 60-inch culvert has eliminated a previously mapped split flow above Leland Road inundating homes on Fairbourn Road, Lynbrook Drive and Stoneridge Drive. Additional fill and an additional culvert at Yosemite Drive have reduced overbank flow into the park. The development of an apartment complex above Buchanan road has significantly increased water-surface elevations by the addition of fill and drop structures. However, all improvements in this area do contain all of the 1-percent annual chance flows within their banks.

City of Pleasant Hill

Flooding in Pleasant Hill has been caused by local runoff that exceeded stream channel capacities and has been greatly aggravated by blocked drainage facilities. Along the lower reaches of Grayson Creek, principal flood problems are caused by a lack of channel capacity and constriction of the floodplain by inadequate levees. Beginning with the Center Avenue Bridge, located in the unincorporated areas of Contra Costa County, and proceeding upstream, numerous undersized or poorly maintained bridge crossings cause overbank flooding. In the upper portion of Grayson Creek, south of Viking Drive and continuing on to East Fork Grayson Creek, a concrete box channel constructed in the late 1950s causes overbank flooding. The channel cannot accommodate the 1-percent annual chance flood runoff from the urbanized drainage above it. Overbank flooding also occurs along East Fork Grayson Creek, south of Gregory Lane, and along Murderers Creek because existing channels and crossings cannot convey the 1-percent annual chance peak flows.

Between 1950 and 1980, 16 floods occurred in the study area. Since that time, major flood events have occurred in the region in 1982, 1983, 1986, 1992, 1996, and 1998. In January 1952, 6.75 inches of rain fell in 6 days, and 450 families in eastern Contra Costa County were left homeless. The Pacheco area immediately north of the city limits was especially affected. In December 1955, although 11.75 inches fell in 6 days, less damage occurred than in 1952 because of improved drainage facilities. At the corner of Ardith and Elinora Drives in the Gregory Gardens area, 2.5 feet of water ponded in the road. In 1958, Gregory Gardens flooded for the second time; 2,600 homes were affected. The CCCFCWCD then asked Congress for $24 million to implement flood-control measures.

In 1955 and 1958, flood peaks of 416 and 602 cubic feet per second, respectively, were measured at stream gages on West Fork Grayson Creek. Based on regional analysis, these floods had estimated recurrence intervals of approximately 20 and 50 years, respectively. During a 1963 flood, although the Grayson Creek gage was no longer operating, the peak flow, measured at various gages in the basins south of Pleasant Hill, reflected a recurrence interval of between 10 and 35 years.

City of Richmond

Flooding within the City of Richmond is caused primarily by three factors: undersized culverts at the Union Pacific and Santa Fe Railroads; topography that slopes away from stream banks, creating shallow overland flows and ponding effects; and inundation of coastal areas by tidal flooding.

Garrity Creek, located in northeast Richmond, is a small, intermittent stream whose total drainage area is 2.9 square miles. It lies in a precipitous canyon and will contain the 1-percent annual chance flood in the natural channel.

Rheem Creek, drainage area 1.9 square miles, originates in eastern Richmond, flows into the City of San Pablo and back into western Richmond. The West Richmond channel of Rheem Creek was improved by the USACE in 1960. This portion of the creek is susceptible to flooding during the 1-percent annual chance storm. The East Richmond channel of Rheem Creek has only 0.7 square mile of drainage area, is 500 feet in length and experiences no flooding problems.

San Pablo Creek, drainage area 41 square miles, originates above the dam creating San Pablo Reservoir in Contra Costa County. In this upper portion of the creek, characterized by high velocities, the natural channel will contain the 1-percent annual chance flood. The creek flows from the San Pablo Reservoir dam about 8 miles to San Pablo Bay. On its course to the bay, the creek passes through Contra Costa County and the cities of El Sobrante, San Pablo, and Richmond. Floodflows are retarded within the Richmond city limits at the culverts under the Union Pacific Railroad. The last 1,000 feet of San Pablo Creek are affected by tidal action.

Wildcat Creek, drainage area 8.7 square miles, like San Pablo Creek originates outside the City of Richmond and terminates in San Pablo Bay within the city limits. On its course to the bay, Wildcat Creek traverses Charles Lee Tilden Regional Park and crosses the steep undeveloped canyon area of the eastern sector of the city. The creek crosses into the City of El Cerrito, the City of San Pablo, and the unincorporated area of North Richmond. The creek crosses into or near narrow corridors of the City of Richmond four times. In one of these corridors, between the Santa Fe and Union Pacific railroads, sheet flooding results from overflows entering Richmond through the culverts under the Santa Fe Railroad and being retained at the culverts under the Union Pacific Railroad.

A segment of Wildcat Creek that forms part of the boundary between San Pablo and Richmond (Vale Road to San Pablo Avenue) was studied in detail for the City of San Pablo Flood Insurance Study (Reference 15). A review of the study indicated that the 1- and 0.2-percent annual chance floods are contained within the banks of the natural channel.

Cerrito Creek originates in Kensington, California, and flows for two miles to San Francisco Bay. For the last 2,000 feet, the creek forms the boundary between Richmond and the City of Albany. The north branch of Cerrito Creek extends from the Union Pacific Railroad northeast to the Richmond-El Cerrito city boundary. Cerrito Creek and its branch pass through culverts under the Santa Fe Railroad. Together they create a ponding and sheet-flooding condition for the immediate area (up to 500 yards across) for minimum frequency floods (less than 10 years).

Flooding is also a problem within the City of Richmond where adequate storm drainage is unavailable. Entire city block areas will receive sheetflow waters conveyed along streets from nearby stream overflows. These low-lying block areas will experience ponding buildups of 1.0 foot or more during the 10-percent annual chance storm.

Tidal flooding from the 1-percent annual chance storm in the City of Richmond will affect all areas fronting on San Francisco and San Pablo Bays up to an elevation of six feet. This will cause inundation of the low-lying coastal areas, much of which is marshland. Most development within these areas is situated on fill or natural sediments above the six feet elevation. Those structures that are not, however, are subject to inundation and increased hazards due to wave action.

Although it has been established that a relationship exists between seismic or volcanic disturbances and tsunami, this relationship is not well defined. The potential for tsunami inundation has not been part of this study, but some of the effects of the March 1964 tsunami are noted in the following sentences. The tsunami of March 1964 resulted from an earthquake apparently centered in the Chugach Mountains of Alaska. The magnitude of the disturbance was estimated at from 8.4 to 8.6 on the Richter scale (50 percent greater than the 1906 earthquake in San Francisco). The following wave heights were recorded or observed in the Marin County area (adjacent county to the northwest): a 6.5-foot wave at the entrance to Tomales Bay; a 7.4-foot wave at the Golden Gate, and a 5-foot wave at the Lowries Yacht Harbor in San Rafael. About $80,000 worth of damage to boats and dock facilities occurred in the San Rafael area, directly across the bay from Richmond. On the basis of existing information, it is believed that a tsunami generated by a wave entering the Golden Gate from a distant source would be 50 percent attenuated before it reached the Richmond area.

City of San Pablo

Floodplains along San Pablo Creek and Wildcat Creek can be divided into two distinct regions: upstream of the Union Pacific Railroad crossing and downstream of the Union Pacific Railroad crossing. Throughout the study area, urban development has encroached upon the channel, resulting in little or no natural floodplain within the studied reaches. A cascading effect is produced when flooding occurs. Water first spills from the undersized channel and culvert openings of Wildcat Creek, above the railroad tracks, and flows to San Pablo Creek. This spill combines with flows along San Pablo Creek, which, in turn, backs up against the Union Pacific Railroad and spills over toward Rheem Creek. When the USACE constructed channel improvements through and downstream of the railroad tracks, condensed backwater effects reduced the amount of flow that diverts from Wildcat Creek to San Pablo Creek to Rheem Creek. However, these improvements did little to relieve flooding upstream of the Union Pacific Railroad in urbanized areas.

City of San Ramon

Flooding in San Ramon is caused primarily by winter rains. Floods from San Ramon Creek have occurred in December 1955, April 1958, October 1962, and January 1963.

City of Walnut Creek

Flooding in Walnut Creek is caused primarily by winter rains. The greatest flood damage was caused by the flood of March and April 1958, when 42.8 inches of rainfall was recorded during an 8-day period.

Areas of the city severely damaged by floods in the past include those adjacent to

Walnut, Las Trampas, and San Ramon Creeks, particularly the downtown business district located at the confluence of the three creeks. Figures 2 and 3 show this area during the 1958 flood. Lesser damage from floods has occurred along several of the smaller streams, particularly Tice and Homestead Creeks. The Walnut Boulevard area of Homestead Creek flooded in January 1982.

The primary cause of flooding in Walnut Creek is due to the inadequate capacity of the natural or semi natural channels. While the flood-control capacity of the major hydraulic structures is usually adequate, their effectiveness is reduced by high-water levels in the adjacent channels. This is particularly true of the Capwell Culvert under the central business district. While the culvert has a nominal capacity to carry approximately the 1-percent annual chance flood (Reference 16), high-tail water conditions in the natural channel, opposite the city park, backs up water in the culvert and reduces its capacity by approximately 8,000 cfs. This results in large overflows from San Ramon Creek that must pass through the business district before returning to the channel near the city park. The area extent of the relatively rare 1-percent annual chance flooding determined for this area is similar to that which was experienced during the less rare flooding of April 1958 (a 15- to 10-percent annual chance flood).

Contra Costa County (Unincorporated Areas)

The sources of flooding along Mitchell Creek and Mount Diablo Creek are primarily attributed to inadequate bridge crossings. In the lower portion of Mount Diablo Creek overbank flooding occurs between Bailey Road and Concord Boulevard due to inadequate channel capacity. At the Concord Boulevard Bridge crossing flow is lost to left overbank flooding down Concord Boulevard due to inadequate capacity at this crossing. At Ayers Road, located in the City of Concord, California, water spills out of the channel onto the left floodplain and flows to Heather Road, which eventually discharges to Galindo Creek. Upstream of Kirker Pass Road, in the Cities of Clayton and Concord, California, the development of a large supermarket and channel widening has altered the floodplain. Mount Diablo Creek does not have the capacity to accommodate the 1-percent annual chance floodflow from Kirker Pass Road to approximately 1,400 feet upstream of Lydia Lane.

The flooding that occurs on Green Valley Creek is caused by lack of channel capacity and undersized, or poorly maintained culverts and bridge crossings.

The sources of flooding along Rodeo Creek are mainly from the undersized rectangular channel beginning at 3rd Street and extending downstream to San Pablo Bay. Overbank flooding is extensive downstream of 4th Street. Upstream of 4th Street the 1- and 0.2-percent annual chance flood discharge is generally contained in the channel with the exception of flooding from the 0.2-percent annual chance flood event breaking out along the west overbank near 6th Street.

Along Garrity Creek the primary sources of flooding pertain mainly to undersized culverts and channel segments. In general, once the flow leaves the channel it flows adjacent to local drainages or floodplain areas. All flow returns to the creek prior to discharging through the Burlington Northern Santa Fe Railway underpass. Two primary flood problems in the study reach are the lack of channel capacity at Brian Road and Tara Hills Drive.

In the lower area of the Grayson Creek study reach, the principal flood problems that occur are caused by a lack of channel capacity and a constriction of the floodplain by inadequate levees. Beginning with the Center Avenue Bridge and proceeding upstream, there are numerous undersized or poorly maintained bridge crossings which cause overbank flooding. In the upper portion of the Grayson Creek study reach, in the City of Pleasant Hill, California, a concrete box channel constructed upstream of Cottonwood Drive in the late 1950s causes overbank flooding. This channel is unable to accommodate the 1-percent annual chance flood runoff from the urbanized drainage above it.

Appian Creek is a small creek with a watershed of approximately 0.98 square miles at its confluence with San Pablo Creek in the City of Richmond, California. The creek's watershed is primarily suburban and moderately urbanized. The upper portions of the watershed have no defined channel. A localized subterranean storm drainage network collects runoff. This system eventually terminates in a semi-natural creek channel. The channel is deeply incised at its confluence with San Pablo Creek and extends into a broad valley filled with commercial properties, apartment buildings and some single-family residential lots. The sources of flooding along Appian Creek are mainly undersized culverts and channel segments and from old hydraulic structures. Examples of this are the culvert under the Santa Rita Apartments, at Appian Way and at Garden Lane. In addition, the channel downstream of the Santa Rita Apartments to Appian Way is heavily overgrown with willows.

There are two major flood problems in the study reach of Arroyo del Hambra Creek: (1) lack of channel and bridge capacity in the lower reach (from Muir Station Road to Tahoe Drive in the City of Martinez, California); and, (2) the Alhambra Avenue Culvert also located in the City of Martinez, California. In the lower sections, flow leaves the channel over both banks. Flow lost over the right bank eventually returns downstream near State Highway 4 where it re-enters at a long culvert. Flow that leaves the left bank moves into a depression area to the west. Flows accumulate in this depression, causing shallow flooding. The second area of flooding occurs upstream of the Alhambra Avenue crossing. Lack of culvert capacity and an old hydraulic structure immediately upstream of the culvert cause backwater effects to spill from the channel. Water spills at the culvert headwall causing flow to move both east and west along Alhambra Avenue. The old hydraulic structure further compounds the problem, increasing the backwater problem and causing shallow flooding to the west.

Flooding along West Alamo Creek is, for the most part, immediately adjacent to the channel with the exception of some overbank flooding due to an undersized culvert at Green Meadow Drive. The lower portion of West Alamo Creek terminates in a detention basin which is located just upstream of Mansfield Drive Upstream of this point West Alamo Creek is an earthen channel with two drop structures and a flow control weir. An excavated channel area upstream of the Green Meadow Drive culvert acts as a detention basin. The natural earth channel continues upstream to Blackhawk Meadow Drive.

The floodplains along Wildcat and San Pablo Creeks can be divided into two distinct regions - upstream of the Union Pacific Railroad crossing and downstream of the crossing. Throughout the study area, urban development has encroached upon the channel. There is little or no natural floodplain throughout the studied reaches. When flooding occurs it produces a cascading effect. Water first spills from the undersized channel and culvert openings of Wildcat Creek above the railroad tracks and begins to flow over to San Pablo Creek. This spill combines with the flows along San Pablo Creek, which in turn backs up against the railroad and begins to spill over to Rheem Creek. When the USACE constructed channel improvements through and downstream of the railroad tracks, they reduced the backwater effects, thus reducing the amount of flow, which diverts from Wildcat Creek to San Pablo Creek to Rheem Creek. However, these improvements did little to relieve flooding upstream of the Union Pacific Railroad in the urbanized areas. The 1-percent annual chance flood discharge along San Pablo Creek is contained within the channel in the unincorporated areas of Contra Costa County.

The flooding that occurs on Line A, DA-40 is a result of inadequate capacity in the 10-foot diameter storm drain for peak flows upstream of Howe Road, with subsequent overland flow occurring along the same alignment as the storm drain during a 1-percent annual chance storm event resulting in depths of flow of less than one foot. The study reach of Line A, DA-40 consists of an existing 10-foot diameter storm drain extending from the upstream limits of the study area downstream to Howe Road. The storm drain alignment follows several roads and crosses under the backyards of several houses in the subdivision. For the remainder of the study area, located in the City of Martinez, California, Line A, DA-40 consists of a grass-lined trapezoidal shaped open channel. The open channel then flows into a long culvert underneath the Shell Oil Refinery, eventually discharging into tidal wetlands. The flooding along Line A, DA-40 during a 1-percent annual chance storm event in the unincorporated areas of Contra Costa County is overland flooding with a depth of less than 1 foot.

2.4 Flood Protection Measures

The rapid residential development of central Contra Costa County communities during the 1950s and 1960s brought about a rapid increase in runoff. To cope with the increased runoff, the USACE has proposed, designed, and partially constructed the Walnut Creek Project. Elements of the project include channel shaping, concrete channel lining, improved bridge designs, new culverts and culvert entrances, and levee improvement and construction. To date, the project is completed through Phase II, which includes, among other things, concrete lining on much of Walnut Creek; 1-percent annual chance flood capacity culverts and channels on the lowermost portions of Pine and Galindo Creeks; and 1-percent annual chance flood levees along portions of Grayson Creek. As a separate project, the USACE constructed a flood channel with a 2-percent annual chance nominal capacity on Rodeo Creek.

The CCCFCWCD, with the assistance of the NRCS, have completed a number of projects throughout the county. Among these are the Marsh-Kellogg Watershed Plan (Reference 17) in the eastern, or delta, region. This consists principally of the Marsh Creek flood detention reservoir located at the edge of the foothills south of Brentwood and improvement of 36 miles of channel on Marsh, Sand, and Deer Creeks. These channels were designed to carry the 2-percent annual chance flood. channel improvements have been made on various segments of San Ramon and Las Trampas Creeks. Grayson Creek channelization was also an NRCS project before it was incorporated into the Walnut Creek Project. A flood detention basin was recently completed on Pine Creek.

Levees exist in the study area that provide the community with some degree of protection from flooding. However, it has been ascertained that some of these levees may not protect the community from rare events such as the 1-percent annual chance flood. The criteria used to evaluate protection against the 1-percent annual chance flood are 1) adequate design, including 3 feet of freeboard, 2) structural stability, and 3) proper operation and maintenance. Levees that do not protect from the 1-percent annual chance flood are not considered in the hydraulic analysis of the 1-percent annual chance flood plain.

City of Antioch

Flood protection structures in Antioch include improved channels through recently developed areas. Reaches of improved channels are located on Markley Creek, between State Highway 4 and the Union Pacific Railroad tracks, and on West Antioch Creek, from 1,000 feet upstream to 1,300 feet downstream of Putnam Road and from State Highway 4 to the Union Pacific Railroad tracks. These channels offer limited protection for the adjacent residential areas from the 1-percent annual chance flood event.

Table 5: Historic Floods

Stream Name and Location	Gage Number (11-)	Drainage Area (sq. mi.)	Peak Discharge/Estimated Recurrence Interval (cfs)			
			December 1955	April 1958	October 1962	January 1963
			Approximate Recurrence Interval if Available			
Pinole Creek At Pinole	1821	10.1	697	1,660/50	797	639
San Ramon Creek At San Ramon	1825	5.9	1,350/22	1,450/30	1,600/36	1,250/18
San Ramon Creek At Walnut Creek	1830	50.8	6,890/22	6,530/20	4,500	7,980/30
Walnut Creek At Walnut Creek	1835	79.2	11,000/11	12,200/15	3,200	10,900/11
Marsh Creek Near Byron	3375	42.6	3,800/17	3,380/13	200	3,880/17

West Branch East Antioch Creek is channelized by levees in low-flow conditions. However, these structures were not designed for flood control, and as such, do not provide protection from the 1-percent annual chance recurrence interval flood.

Flooding from Cavallo Drain has been eliminated with the installation of a sixty-inch diameter culvert that supplements the storm drainage capability provided by the existing forty-eight inch culvert.

City of Brentwood

There are no known principal flood protection measures within the City of Campbell.

City of Clayton

After the 1963 flood, Clayton joined with adjacent communities to request a flood control report from the county flood control district and the local soil conservation district (Reference 18). The report, completed in 1967, recommended small flood control dams on Mount Diablo and Mitchell Creeks. This project was never constructed.

Numerous drainage improvements were installed as part of the Oakhurst Country Club development including large box culverts on Mount Diablo and Mitchell Creeks. In addition, a large detention basin was constructed on Peacock Creek, which is designed to slightly reduce the 1-percent annual chance floodflow along Mount Diablo Creek.

City of Concord

Existing flood protection measures include sections of improved channel along parts of all of the study streams.

All of Walnut Creek within the City of Concord has been improved by the USACE to contain the 1-percent annual chance flood. Walnut Creek is lined with leveed banks, which are maintained by Contra Costa County. The levees are elevated more than 3 feet above the 1-percent annual chance flood level for most of the reach within the city. Overbank areas along most of the leveed banks are elevated higher than the levees. However, levees along the left overbank north of Willow Pass Road are elevated less than 3 feet above the 1-percent annual chance flood. A section of the Walnut Creek levee is being de-accredited.

The USACE has completed part of a channel improvement project designed to contain the 1-percent annual chance flood along the lower reaches of Pine and Galindo Creeks. The completed improvements include a concrete-lined channel along Pine Creek downstream of the bay area rapid transit tracks. A drainage channel has been constructed along Galindo Creek from San Miguel Road to the confluence with Pine Creek. This is a significant improvement, as it will eliminate a large overflow from Monument Boulevard.

Most of the remaining streams have sections of channels, which have been improved by local agencies, but in most cases the improvements are still not able to handle the 1-percent annual chance flood. Stream channels that have been improved include most of Clayton Valley Drain, a section of Farm Bureau Road Drain between Walnut Avenue and Farm Bureau Road, a section of Mt. Diablo Creek near Concord Boulevard, sections of Galindo Creek between Ygnacio Valley Road and Academy Road and downstream of Treat Boulevard, most of Pine Creek within the city, and most of Ditch No. 2.

Levees have been constructed along Clayton Valley Drain near the confluence with Walnut Creek. Below Solano Way there is greater than 3 feet of freeboard between the top of levees and the 100year flood along Clayton Valley Drain. Upstream of Solano Way there is less than 3 feet of freeboard. Along the right overbank, the levee-protected area is flooded by 1-percent annual chance overflows originating further upstream from Clayton Valley Drain. Approximate 1-percent annual chance flood boundaries have been determined for the levee-protected area along the left overbank.

Town of Danville

The CCCFCWCD, with assistance from the NRCS, has reshaped and widened segments of San Ramon, Sycamore, and Green Valley Creeks. Drop structures have been added along San Ramon and Sycamore Creeks. No flood plain management measures have been undertaken in Danville.

City of El Cerrito

There are no flood protection measures currently in existence in the City of El Cerrito.

City of Hercules

No flood protection facilities exist along Refugio Creek, although improved channels are expected as development in the city increases.

The section of Pinole Creek that borders the City of Hercules is in a channel constructed by the USACE in 1966 to convey the 2-percent annual chance flood with 2 feet of freeboard (Reference 14).

City of Lafayette

Flood protection measures in Lafayette are limited to channel improvements on one part of Lafayette Creek. In 1956, a length of approximately 2000 feet of Lafayette Creek was channelized between Moraga Road and Third Street. The rectangular, concrete lined channel will contain the 2-percent annual chance floodflow, but not the 1-percent annual chance flood or 0.2-percent annual chance floodflow.

City of Martinez

The storm drain system in Martinez is not designed to protect the city against a flooding event of 1-percent annual chance recurrence interval. No other flood protection measures are existing or planned that would affect flooding in Martinez.

Town of Moraga

Flood protection facilities in Moraga are limited to a section of improved channel with two drop structures on Moraga Creek where it runs through the Moraga Country Club. The structures have little effect on the 1- and 0.2-percent annual chance floods.

City of Oakley

The CCCFCWCD, with the assistance of the NRCS, have completed a number of projects throughout the county. Among these are the Marsh-Kellogg Watershed Plan (Reference 5) in the eastern, or delta, region. This consists primarily of the Marsh Creek flood detention reservoir located at the edge of the foothills south of Brentwood and improvement of 36 miles of channel on Marsh, Sand, and Deer Creeks. These channels were designed to carry the 2-percent annual chance flood. The lower reaches of Marsh Creek Channel flow through the City of Oakley.

City of Orinda

At present, there are no major flood protection structures within the City of Orinda. The only structures of any significance are some drainage culverts, which pass the normal flow of the streams in the city.

City of Pinole

In June 1966, the USACE completed a trapezoidal open channel construction program on the stream reach between Interstate Highway 80 and San Pablo Bay. The channel was designed to convey the 2-percent annual chance flood with 2 feet of freeboard (Reference 14).

No other flood-control structures exist on the Pinole Creek in the City of Pinole.

City of Pittsburg

Pittsburg is afforded flood protection, either directly or indirectly, by essentially every flood control influencing inflow to the Delta area. This includes 17 major dams and reservoirs on the main stem and tributary streams from the upper Sacramento River in Shasta County on the north to the upper San Joaquin River in Fresno County_ on the south. Other storage projects in the Central Valley are authorized but not started or in preauthorization study stage. NOTE: Projects in the Tulare Lake Basin are excluded from this discussion because the possibility of floodwater overflowing from that basin is extremely remote. The last such overflow occurred in 1878.

Each major storage project in the Central Valley comprises a unit of a comprehensive, integrated system that includes levees, improved channels, floodway bypasses, and other improvements for flood control as well as storage projects. Additional project works to augment the protection that is presently provided are being considered by the USACE in ongoing investigations of flood control and related water resources development problems in the Central Valley.

All of the waterways under study in the Delta area are leveed. These levees are classified as nonproject. Direct agreement levees were either constructed as part of a navigation project or rebuilt by the Federal Government after a flood and are maintained by local reclamation districts to Federal standards. These levees constitute only about 10 percent of the total levee system. Project levees were either constructed by local interests and then rebuilt to Federal standards or adopted as part of a Federal flood control project. About 15 percent of the Delta levee system falls into this category and is maintained to Federal standards by local interests. Nonproject levees were privately constructed, are maintained by private owners or local agencies, and often receive minimal maintenance that is rarely performed to any kind of uniform standards. About 75 percent of the Delta levees are in this category.

The City of Pittsburg has a floodplain development ordinance that restricts development in the special flood hazard zones. In 1968 the city initiated plans for channel improvements along Kirker Creek. Sections of the improvement have been implemented (Reference 19). There are no other flood protection measures being taken in Pittsburg.

City of Pleasant Hill

In response to the 1958 request by the CCCFCWCD, the U.S. Department of Agriculture NRCS constructed flood channels on Grayson Creek and its East and West Forks in the early 1960s. Approximately 2.4 miles of rectangular concrete channel was constructed along Grayson Creek from 335 feet upstream of Viking Drive upstream to the confluence with East and West Forks, along East Fork Grayson Creek from the confluence upstream to Gregory Lane, and along West Fork Grayson Creek from the confluence upstream to the vicinity of the intersection of Mercury Way and Apollo Way.

On the downstream portion of Grayson Creek, the NRCS constructed a trapezoidal earthen channel, and the USACE subsequently raised the height of the leveed banks. The NRCS project was completed before the 1963 flood.

The revised analyses along Grayson Creek and East Fork Grayson Creek revealed that these flood protection measures along Grayson Creek and East Fork Grayson Creek are no longer sufficient to convey a 1-percent annual chance flood event. The West Fork Grayson Creek channel was not restudied as part of this study, but it is assumed adequate to convey a 0.2-percent annual chance flood event.

City of Richmond

Two small reservoirs on Wildcat Creek are located within the confines of Charles Lee Tilden Regional Park. These reservoirs, Jewel Lake and Lake Anza, which intercept runoff from a total area of three square miles at the upper part of the basin, are utilized for recreation, and their influence on flood runoff at downstream points is insignificant. Two relatively large reservoirs on San Pablo Creek are owned and operated by the East Bay Municipal Utility District. These reservoirs are primarily utilized as terminal storage reservoirs for water imported by aqueduct from Pardee and Comanche reservoirs on the Mokelumne River in the Sierra Nevada but are also used to develop some yield from local runoff. No flood control storage is provided in these reservoirs, but drawdown during the dry summer months provides some storage during most winter months, which results in incidental flood control storage.

As previously mentioned, the West Richmond channel of Rheem Creek was improved in 1960 by the USACE to facilitate better drainage of backwater from the City of San Pablo and to decrease flooding occurrence in the West Richmond area.

Offshore breakwaters exist in some bay locations. Their purpose is to protect channels from silting and harbor structures from wear due to wave action. Tidal flooding as a result of tsunamis and wind driven waves is diminished in locations protected by these breakwaters. Storm tides and swells will experience little effect from the breakwaters.

In 1973, a list of alternatives for improving flood protection measures were suggested by the USACE for the flood plain regions of San Pablo and Wildcat Creeks in a feasibility report for water resources development (Reference 20). Implementation of any proposal is dependent on planning and funding approvals of the various levels of governments involved. None of the suggested improvements were planned for construction at the time this study was made.

City of San Pablo

In 1995, the USACE performed channel improvement work along San Pablo and Wildcat Creeks downstream of the railroad embankments by adding a concrete-lined channel. These improvements are accounted for in the restudy, but this work did not eliminate flooding upstream of the embankments. Because the main cause of flooding is blockage at the railroad culverts, the city has a channel maintenance program designed to keep debris from collecting at these areas. This maintenance program is accomplished each year in August before the flood season, which starts in November and runs through March, and consists of cleaning the creek channels and repairing erosion-control devices.

City of San Ramon

Major channel improvements have been constructed along South San Ramon Creek beginning about 2,500 feet upstream of Alcosta Boulevard and extending upstream to its confluence with Coyote Creek.

City of Walnut Creek

Existing flood protection measures include sections of improved channel along parts of most of the study streams. Various segments of Walnut, San Ramon, and Las Trampas Creeks have been improved by the USACE, the State of California, or local interests.

The USACE Walnut Creek Project includes a rectangular, concrete lined channel from Bancroft Road at the northern corporate limits to the Union Pacific Railroad tracks just south of Ygnacio Valley Road on Walnut Creek. Similar improvements were constructed by Caltrans on San Ramon Creek in the vicinity of Creekside Drive and Rudgear Road. These channels were designed to handle the 1-percent annual chance flood. A 0.5-mile segment of covered channel, locally known as the Capwell Culvert, underlies the central business district in the vicinity of Mt. Diablo Boulevard. The culvert was originally built by local interests and extended as part of the Walnut Creek Project. Other portions of San Ramon Creek have been reshaped to improve capacity south of the confluence with Walnut Creek.

Las Trampas Creek has also been reshaped between its confluence with Walnut Creek and the corporate limits. Tice Creek has been improved by constructing an underground rectangular channel between the confluence with Las Trampas Creek and Lilac Drive and a rectangular channel between Lilac Drive and Orchard Lane. Two bypasses on Homestead Creek divert flow to the west into the Walnut Creek channel. One bypass, consisting of two underground 72-inch pipes, diverts flow from the natural channel just north of Ygnacio Valley Road to Walnut Creek. Another bypass, with a 96inch underground pipe with an inlet structure at Brasero Lane, diverts flow from this point into Walnut Creek. The 96-inch pipe has a capacity of 470 cfs, while the 1-percent annual chance flood discharge is 700 cfs at the inlet structure. However, this is sufficient to prevent overbank flooding on Homestead Creek downstream of Brasero Lane during a 1-percent annual chance flood event. The upper reach of East Fork Grayson Creek between Sunnyvale Avenue and the Contra Costa Canal has been replaced with two 54-inch pipes.

Contra Costa County (Unincorporated Areas)

The rapid residential development of central Contra Costa County communities during the 1950s and 1960s brought about a rapid increase in runoff. To cope with increased runoff, the USACE has proposed, designed, and partially constructed the Walnut Creek Project. Elements of the project include channel shaping, concrete channel lining, improved bridge designs, new culverts and culvert entrances, and levee improvement and construction. To date, the project is completed through Phase II, which includes, among other things, concrete lining on much of Walnut Creek; 1-percent annual chance flood capacity culverts and channels on the lowermost portions of Pine and Galindo Creeks; and 1-percent annual chance flood levees along portions of Grayson Creek. As a separate project, the USACE constructed a flood channel with a 2-percent annual chance nominal capacity on Rodeo Creek.

The CCCFCWCD, with the assistance of the NRCS, have completed a number of projects throughout the county. Among these is the Marsh-Kellogg Watershed Plan (Reference 6) in the eastern, or delta, region. This consists principally of the Marsh Creek flood detention reservoir located at the edge of the foothills south of Brentwood and improvement of 36 miles of channel on Marsh, Sand, and Deer Creeks. These channels were designed to carry the 2-percent annual chance flood. channel improvements have been made on various segments of San Ramon and Las Trampas Creeks. Grayson Creek channelization was also an NRCS project before it was incorporated into the Walnut Creek Project. A flood detention basin was recently completed on Pine Creek.

Levees exist in the study area that provide the community with some degree of protection from flooding. However, it has been ascertained that some of these levees may not protect the community from rare events such as the 1-percent annual chance flood. The criteria used to evaluate protection against the 1-percent annual chance flood are 1) adequate design, including 3 feet of freeboard, 2) structural stability, and 3) proper operation and maintenance. Levees that do not protect from the 1-percent annual chance flood are not considered in the hydraulic analysis of the 1-percent annual chance flood plain.

3.0 ENGINEERING METHODS

For the flooding sources studied in detail in the community, standard hydrologic and hydraulic study methods were used to determine the flood hazard data required for this FIS. Flood events of a magnitude, which are expected to be equaled or exceeded once on the average during any 10-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 10-, 50-, 100-, and 500-year floods, have a 10-, 2-, 1-, and 0.2-percent chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long-term average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. For example, the risk of having a flood, which equals or exceeds the 1-percent annual chance flood in any 50-year period is approximately 40 percent (4 in 10), and, for any 90-year period, the risk increases to approximately 60 percent (6 in 10). The analyses reported herein reflect flooding potentials based on conditions existing in the community at the time of completion of this FIS. Maps and flood elevations will be amended periodically to reflect future changes.

3.1 Hydrologic Analyses

Hydrologic analyses were carried out to establish the peak discharge-frequency relationships for each flooding source studied in detail affecting the community.

For each community within Contra Costa County that had a previously printed FIS report, the hydrologic analyses described in those reports have been compiled and are summarized below.

City of Antioch

There are no gaging stations on the streams in Antioch. Discharges for Los Medanos Wasteway, West Antioch Creek, Middle Branch West Antioch Creek, Markley Creek, West Branch East Antioch Creek, and Hillcrest Branch East Antioch Creek were obtained using a regional regression analysis developed by Tudor Engineering Company for the central-delta region of Contra Costa County. The records from 15 stream gaging stations containing 278 measured annual flow peaks (Reference 21) were utilized to establish the peak discharge frequency relationship at the stations in accordance with U.S. Water Resources Council procedures (Reference 22). The relationships developed at the gaging station were transferred to ungaged basins by means of the statistical technique of stepwise multiple regression. The significant basin characteristics were drainage area and mean annual precipitation.

Data obtained from the California Department of Water Resources for rain gages in the Antioch region (Reference 23) were analyzed using NRCS procedures (Reference 24) to generate peak discharges on East Antioch Creek for storms with recurrence intervals of 10-, 50-, 100- and 500- years. The NRCS computer program TR-20 (Reference 25) was used to model the basin and peak flow-frequency curves were derived.

Certain special situations require additional analyses. Floodflow from basins that have undergone significant urbanization were adjusted upward in accordance with the percentage of the drainage area that was urbanized and was served by improved major drainage channels. On East Antioch Creek, ponding at Lake Alhambra has sufficient flood storage potential to reduce floodflow peaks. Flood hydrograph and reservoir-routing methods were used to determine peak outflow from these storage areas. Outflow from Lake Alhambra is affected by a concurrent normal high tide (Mean Higher High Water) of 3.5 feet. This condition was reflected in this Flood Insurance Study.

City of Brentwood

There is no hydrologic data available at this time.

City of Clayton

For the original study, peak discharges were based on a regional regression analysis developed by the study contractor for the Central-Delta region of Contra Costa County. The records from 14 stream gaging stations containing 264 measured annual flow peaks (Reference 21) were utilized to establish the peak discharge-frequency relation at the stations in accordance with U.S. Water Resources Council procedures (Reference 22). There is no applicable stream gaging station near Clayton; however, the stations selected depict a hydrologic region similar to the Clayton area and include a small basin in the upper Mouth Diablo Creek drainage, as well as Marsh Creek and San Ramon Creek, which drain the east and west slopes of Mount Diablo, respectively. The relationships developed at the gaging stations were transferred to ungaged basins by means of the statistical technique of stepwise multiple regression. The significant basin characteristics were drainage area and mean annual precipitation.

The peak discharges used for the restudy were obtained from CCCFCWCD who developed these discharge values using the HYDRO-H hydrologic computer program (Reference 26).

CCCFCWCD collects precipitation data and has developed mean seasonal precipitation isohyetal maps and precipitation depth-duration-frequency curves for Contra Costa County. A total of 76 rain gages, which are maintained by the National Weather Service, the East Bay Municipal Utility district and CCCFCWCD, have been used to develop this information. CCCFCWCD has adopted a unit hydrograph approach to determine peak runoff conditions, which incorporates USACE procedures for developing the unit hydrograph, which are very similar to the USACE program HEC-1 (Reference 27). CCCFCWCD has developed their HYDRO-II program to compute and plot hydrographs. This program uses the relationship between lag time and time rate-of-change of runoff to construct synthetic unit hydrographs. The time rate of change of runoff "S" curves, as well as infiltration and base flow assumptions, were adopted by CCCFCWCD utilizing procedures and previous studies conducted by USACE within the County. HYDRO-II also has routing capabilities. Watershed routing is based on Tatum routing procedures that were adopted by USACE. On- and off-site detention basins may be routed using the program.

City of Concord

Walnut Creek flood estimates are based on an analysis of 16 years of records (Reference 21) from the Walnut Creek U.S. Geological Survey Gage (No. 11183500), which is located 2 miles upstream of the Concord corporate limits. The study contractor performed a regional flood peak regression analysis for Walnut Creek. The results of these analyses were very similar to discharges previously adopted by the USACE for the Walnut Creek Project (Reference 28) and to the results of regional flood peak regression equations independently developed by the U.S. Geological Survey (Reference 29).

U.S. Geological Survey stream gages were operated on Galindo Creek (No. 11184000) for 4 years on Pine Creek (No. 11184500) for 8 years; the record, however, was too short for direct use in determining the flood frequency. The flood peak estimates for Pine and Galindo Creeks, Ditch No. 2, Clayton Valley Drain, and Farm Bureau Road Drain were based primarily on the U.S. Geological Survey's Central Coast regional regression equations published in Magnitude and Frequency of Floods in California, Water Resources Investigation 77-21 (Reference 29).

The results for the 1-percent annual chance flood are on average 10 percent lower than those determined for an unpublished Flood Insurance Study prepared for FEMA by the USACE in September 1971 (Reference 30). They are considerably lower than discharges determined by the USACE for the ultimate development of the area projected in the year 2020 (Reference 31).

Flood peak estimates for Mt. Diablo Creek were based on regional regression equations developed by the study contractor for the Central-Delta region of Contra Costa County in accordance with the U.S. Water Resources Council procedures (Reference 32). A 1-percent annual chance overflow occurs along the left overbank of Mt. Diablo Creek at

Ayers Road and flows as Zone B shallow flooding to Galindo Creek and Farm Bureau Road Drain. Peak 1-percent annual chance flood discharges downstream of Ayers Road along Mt. Diablo Creek reflect the overflow loss of 1,071 cfs.

The peak discharges used for the restudy were obtained from CCCFCWCD who developed the discharge values using their HYDRO-II hydrologic computer program (Reference 26).

CCCFCWCD collects precipitation data and has developed mean seasonal precipitation isohyetal maps and precipitation depth-duration-frequency curves for Contra Costa County. A total of 76 rain gages, which are maintained by the National Weather Service, the East Bay Municipal Utility District and CCCFCWCD, have been used to develop this information. CCCFCWCD has adopted a unit hydrograph approach to determine peak runoff conditions, which incorporates USACE procedures for developing the unit hydrograph, which are very similar to the USACE program HEC-1 (Reference 27). CCCFCWCD has developed their HYDRO-II program to compute and plot hydrographs. This program uses the relationship between lag time and time rate-of-change of runoff to construct synthetic unit hydrographs. The time rate of change of runoff "S" curves, as well as infiltration and base flow assumptions, were adopted by CCCFCWCD utilizing procedures and previous studies conducted by USACE within the County. HYDRO-II also has routing capabilities. Watershed routing is based on Tatum routing procedures that were adopted by USACE. On- and off-site detention basins may be routed using the program.

Town of Danville

Peak discharges were based on a regional regression analysis developed by the study contractor for use in this study. The records of nearby stream-gaging stations containing annual flood peaks (Reference 33) were utilized to establish the peak discharge-frequency relationships at the station in accordance with the U.S. Water Resources Council procedures (Reference 21). As there were no stream gages located on the particular stream reaches included in this Flood Insurance Study, the relationships developed at the gaging stations were transferred to the ungaged basins by means of the statistical technique of stepwise multiple regression. The significant basin characteristics were drainage area and mean annual precipitation. Where appropriate, peak discharges were increased to reflect the effects of urbanization of the many suburban subdivisions. These adjustments were based on that portion of the tributary basin that has been developed and channelized.

The peak discharges used for the restudy were developed by CCCFCWCD using their HYDRO-II hydrologic computer program (Reference 26).

CCCFCWCD collects precipitation data and has developed mean seasonal precipitation isohyetal maps and precipitation depth-duration-frequency curves for Contra Costa County. A total of 76 rain gages, which are maintained by the National Weather Service, the East Bay Municipal Utility District and CCCFCWCD, have been used to develop this information. CCCFCWCD has adopted a unit hydrograph approach to determine peak runoff conditions which incorporate USACE procedures for developing the unit hydrograph which are very similar to the USACE program HEC-1 (Reference 14). CCCFCWCD has developed their HYDRO-II program to compute and plot hydrographs. This program uses the relationship between lag time and time rate-of-change of runoff to construct synthetic unit hydrographs. The time rate of change of runoff "S" curves, as well as infiltration and base flow assumptions, were adopted by CCCFCWCD utilizing procedures and previous studies conducted by USACE within the County. HYDRO-II also has routing capabilities. Watershed routing is based on Tatum routing procedures that were adopted by USACE. On- and off-site detention basins may be routed using the program.

City of El Cerrito

An isohyetal map of mean annual precipitation was supplied by the USACE. From this information, peak flow hydrographs and flood volumes for precipitation amounts of the selected recurrence intervals were computed. The peak flow hydrographs were then routed along the channel to obtain outflow hydrographs at each cross section as outlined by the NRCS Design Hydrograph Method (Reference 34).

City of Hercules

These analyses were based primarily on a statistical analysis of 35 years of discharge recorded at the Pinole Creek stream gaging station located in the adjacent basin just south of the Refugio Creek basin. The gage (No. 11182110) has been operated by the East Bay Municipal Utility District continuously since December 1938 (Reference 35). The standard log-Pearson Type III method was used, as outlined by the U.S. Water Resources Council (Reference 22), in conjunction with a regional skew coefficient identified by the study contractor.

This gage site discharge-frequency relationship was adjusted for downstream changes in drainage area and precipitation on the basis of a regional regression analysis developed by the study contractor from the analysis of discharge records of 14 hydrologically similar gaging stations and their drainage basin characteristics.

Peak discharge-drainage area relationships for Refugio Creek, East Branch Refugio Creek, West Branch Refugio Creek, and Pinole Creek are shown in Table 6, “Summary of Discharges.”.

For tidal flooding of lower portions of Pinole Creek and Refugio Creek and for approximate studies of tidal flooding along San Pablo Bay, peak elevation-frequency relationships were established by integration of analyses of San Francisco Bay (Reference 36) and the Sacramento Delta (Reference 37).

City of Lafayette

Since there are no gaging stations on the streams draining Lafayette, peak discharges were based on a regional regression analysis developed by the study contractor for the Central-Delta region of Contra Costa County. In accordance with U.S. Water Resources Council procedures (Reference 22), a peak discharge-frequency relationship was established from the records of 15 stream gages containing 278 measured annual flood peaks (Reference 21). These gages, which include gages located on adjacent Walnut Creek and San Ramon Creek, depict drainage basins hydrologically similar to those in Lafayette.

A stepwise multiple regression was then used to transfer the relationships developed for the gaging stations to the ungaged basins in Lafayette. Where appropriate, peak discharges were increased to reflect the effects of urbanization within Lafayette. These adjustments were based on the proportion of the tributary basin, which has been developed and channelized.

The peak discharges used for the restudy were obtained from CCCFCWCD who developed the discharge values using their HYDRO-II hydrologic computer program (Reference 26).

CCCFCWCD collects precipitation data and has developed mean seasonal precipitation isohyetal maps and precipitation depth-duration-frequency curves for Contra Costa County. A total of 76 rain gages, which are maintained by the National Weather Service, the East Bay Municipal Utility District and CCCFCWCD, have been used to develop this information. CCCFCWCD has adopted a unit hydrograph approach to determine peak runoff conditions, which incorporates USACE procedures for developing the unit hydrograph, which are very similar to the USACE program HEC-1 (Reference 27). CCCFCWCD has developed their HYDRO-II program to compute and plot hydrographs. This program uses the relationship between lag time and time rate-of-change of runoff to construct synthetic unit hydrographs. The time rate of change of runoff "S" curves, as well as infiltration and base flow assumptions, were adopted by CCCFCWCD utilizing procedures and previous studies conducted by USACE within the County. HYDRO-II also has routing capabilities. Watershed routing is based on Tatum routing procedures that were adopted by USACE. On- and off-site detention basins may be routed using the program.

Reliez Creek was studied using detailed methods from approximately 150 feet downstream of Tunnel Road to approximately 3,340 feet upstream of Stanley Boulevard, a total distance of approximately 7,460 feet, within the City of Lafayette. In general, flow capacities at crossings cannot convey 1-percent annual chance peak flows and force significant overbank flooding to occur along portions of Reliez Creek.

The 10-, 50-, and 1-percent annual chance peak flows used in the restudy of Reliez Creek were based upon the hydrologic analysis performed by the City of Lafayette under their Drainage Master Plan (Reference 181), which used peak flows for Reliez Creek determined in the hydrology report published by Contra Costa County (Reference 182). The peak 10-, 50-, and 1-percent annual chance floodflows were calculated by Contra Costa County at the lowest point in the watershed. The City of Lafayette then used this value to determine a unit runoff coefficient for each recurrence interval by dividing each peak flow value by the total drainage area of the basin.

The City of Lafayette then subdivided the watershed into subbasins and measured each specific subarea, routed the subareas into Reliez Creek and calculated the peak flow by multiplying the unit runoff factor by the contributing drainage area at that point.

City of Martinez

For the original study, floodflow-frequency data were estimated for Alhambra Creek (now called Arroyo del Hambra) by use of a synthetic unit hydrograph developed from gage data on Pinole Creek, located immediately to the west of the Alhambra Creek basin. Aiding in the analyses were historic high-water marks. These data were developed earlier by the USACE, San Francisco District, and compiled formally into "The Review Report for Flood Control and Allied Purposes for Alhambra Creek" (Reference 38). Franklin Creek discharges were calculated using the rational method.

The peak discharges used for the restudy were obtained from CCCFCWCD who developed these discharge values using their HYDRO-lI hydrologic computer program (Reference 26).

CCCFCWCD collects precipitation data and has developed mean seasonal precipitation isohyetal maps and precipitation depth-duration-frequency curves for Contra Costa County. A total of 76 rain gages, which are maintained by the National Weather Service, the East Bay Municipal Utility district, and CCCFCWCD have been used to develop this information. CCCFCWCD has adopted a unit hydrograph approach to determine peak runoff conditions, which incorporate USACE procedures for developing the unit hydrograph, which are very similar to the USACE, program HEC-1 (Reference 27). CCCFCWCD has developed their HYDRO-11 program to compute and plot hydrographs. This program uses the relationship between lag time and time rateof-change of runoff to construct synthetic unit hydrographs. The time rate of change of runoff "S" curves, as well as infiltration and base flow assumptions, were adopted by CCCFCWCD utilizing procedures and previous studies conducted by USACE within the county. HYDRO-II also has routing capabilities. Watershed routing is based on Tatum routing procedures that were adopted by USACE. On- and off-site detention basins may be routed using the program.

Town of Moraga

Peak discharges were based on a regional regression analysis developed by the study contractor for the Central-Delta region of Contra Costa County. The records of 16 stream-gaging stations containing 278 measured annual flood peaks (Reference 21) were utilized to establish the peak discharge-frequency relationships at the stations in accordance with U.S. Water Resources Council procedures (Reference 22). There are no gaging stations on the streams draining the Town of Moraga; however, the gaging stations selected depict drainage basins hydrologically similar to the Moraga drainages. They include two gages in the San Ramon Creek basin, located approximately 5 miles east of Moraga and contiguous with the Las Trampas Creek basin (22 annual flood peaks for each gage, from 1955 through 1977).

The relationships developed at the gaging stations were transferred to the ungaged basins by means of the statistical technique of stepwise multiple regression. The significant basin characteristics were drainage area and mean annual precipitation. Where appropriate, peak discharges were increased to reflect the effects of urbanization within Moraga. These adjustments were based on that portion of the tributary basin, which has been developed and channelized.

Peak discharge-drainage area relationships for the streams studied in detail are shown in Table 6, "Summary of Discharges.".

The Upper San Leandro Reservoir maximum water-surface elevations were computed for selected recurrence intervals using data supplied by the East Bay Municipal Utility District (correspondence dated July 20, 1978). Backwater elevations from the reservoir were superimposed on the natural water-surface elevations for reaches within Moraga.

City of Oakley

The unit hydrograph method was used for Marsh Creek and its tributaries. Flood hydrographs were developed for the upper reaches of Marsh Creek, routed through the Marsh Creek flood-control reservoir, and summed with the hydrographs developed for the lower reaches.

Stream discharges were reduced by spills from the channel that flow independently to bypass various stream reaches. Channel spills were particularly large on the lower reaches of Marsh Creek.

The hydraulic regimen of the Sacramento-San Joaquin Delta combines two diametrically opposed water movements-Pacific Ocean tidal action and inflow from tributary river basins. Further complicating the hydraulic system are the numerous interconnecting channels and the variability of delta area inflow. The continual interaction of these elements cause a constant change in the water surface throughout the delta area. Tidal action, tributary basin runoff, and meteorologic conditions are the major factors in influencing delta area water-surface elevations.

Frequency analyses of water-surface elevations in the delta area were performed using the higher-high stage records of 24 gauging stations located throughout the delta area. The selected period of record for the analyses (1945 to 1974) is subsequent to construction of Shasta Dam on the Sacramento River and covers the maximum length of record for the majority of the gages. The delta area hydraulic pattern did not change significantly during that period.

Originally, the stage data were statistically analyzed using the log-Pearson Type III distribution method included in the U.S. Water Resources Council Guidelines (Reference 21). The resultant curves did not reflect either levee overtopping or levee breaks resulting in extensive aerial inundation. Therefore, the shape of the curves was graphically developed to include those conditions. The stage frequency relationship for each gage was compared with the stage frequency relationships developed for adjacent gages and, if necessary, adjusted to obtain consistency.

The Tidal Hydrodynamics Model (a mathematical computer program developed by the California Department of Water Resources), which incorporates a link-node concept to simulate a general estuarine environment of channels and embayments, was used during this study to analyze extreme flow and tide events (larger than 1-percent annual chance flood). The mean daily inflow to the delta area from tributary river basins during six of the largest floods in the area and the corresponding Golden Gate tidal data were input into the model. A comparison of the computed results from the model with the recorded tidal stages for each of the six floods proved satisfactory.

Higher-high stage-frequency profiles were developed for defined channel reaches by connecting a line between the higher-high stage data for each pertinent gage. It should be noted that a stage shown on the stage-frequency curve for one gage is valid only for that particular gage being analyzed. Synthetic higher-high stage profiles for the 50- and 1-percent annual chance flood and larger events were developed for six main channel reaches within the Delta. The 50- and 1-percent annual chance higher-high stage profiles were based on historical flood profiles and the higher-high stage frequency curves. The extreme flow and extreme tide combinations were developed using the Delta Hydrodynamics Model and historical flood profiles. The 10-percent annual chance flood event was extrapolated from a curve developed from 50- and 1- percent annual chance flood data.

The analysis used in this study reflects a static water condition, which includes a combination of river inflow, tidal effect, and wind set.

City of Orinda

Peak discharges for a given stream were developed by various methods. A regional regression analysis developed by the study contractor was the principal method.

Peak discharges developed for San Pablo Creek (Reference 39) were in agreement with the regional values and were adopted for this study.

The peak 1-percent annual chance flood discharges used in the restudy were provided by the CCCFCWCD (Reference 166). These discharges were developed by the County using its "Hydro-Computer Simulation of Rainfall Runoff" (Reference 167) in accordance with its "General Hydrologic Analysis Procedures" (Reference 168). These discharges are generally consistent with those included in the City of Orinda's Storm Drainage Master Plan (Reference 169). The CCCFCWCD hydrologic analyses include the use of a unit-hydrograph method that is based on USACE procedures and parameters developed by the County. Table 6, "Summary of Discharges," summarizes the CCCFCWCD discharges used in this study.

City of Pinole

These analyses were based primarily on a statistical analysis of 35 years of discharges recorded at the Pinole Creek stream gaging station located 0.8 mile upstream of the Pinole corporate limits. The gage (No. 11182110) is operated by the U.S. Geological Survey (Reference 21). The standard log-Pearson Type III method was used as outlined by the U.S. Water Resources Council (Reference 22) in conjunction with a regional skew coefficient identified by Tudor Engineering Company.

This gage site discharge-frequency relationship was adjusted for downstream changes in drainage area and precipitation on the basis of a regional regression analysis. This analysis was developed by Tudor Engineering Company from the analysis of discharge records of 14 hydrologically similar gaging stations and their drainage basin characteristics.

City of Pittsburg

For streams in Pittsburg (excluding the San Joaquin River a1ong Suisun Bay), frequency analyses were based primarily on a regional regression analysis developed by the study contractor for the Central-Delta region of Contra Costa County. The records from 16 U.S. Geological Survey stream gaging stations containing 278 measured annual flow peaks (Reference 13) were utilized to establish the peak discharge-frequency relationships at the stations in accordance with U.S. Water Resources Council procedures (Reference 22). There is no stream gaging station on Kirker Creek, Lawlor Creek, or Los Medanos Wasteway. The relationships developed at the gaging stations were transferred to ungaged basins in Pittsburg by means of the statistical technique of stepwise multiple regression. The significant basin characteristics were drainage area and mean annual precipitation.

Certain special situations required additional analyses. Floodflows from those basins which have undergone significant urbanization were adjusted upward in accordance with the percentage of the drainage area which was urbanized and which was served by improved major drainage channels. On Kirker Creek, overflow behind the Pittsburg-Antioch Highway bypasses much of the floodflows to the east and rejoins Kirker Creek west of Loveridge Avenue, where it again overflows toward New York Slough before it reaches the entrance to the Pittsburg Sewage Treatment Plant at Standard 0il Avenue.

For studies of tidal flooding along San Joaquin River at Suisun Bay (New York Slough), tidal action, tributary basin runoff, and meteorologic conditions are the major factors influencing water-surface elevations associated with the San Joaquin River.

Frequency analyses of water-surface elevations in the San Joaquin River were performed using an analytical study of higher high stage-frequency relationships for 24 gaging stations located throughout the Delta area (Reference 194). The selected period of record for the analyses (1945 to 1974) is subsequent to construction of Shasta Dam on the Sacramento River and covers the maximum length of record for the majority of the gages. Also, the Delta hydraulic pattern has not changed significantly during that period.

For continuity among the gages used in this study, all gage data were adjusted to a datum of zero elevation, North American Vertical Datum (NAVD) of 1988.

Originally, the stage data were statistically analyzed using the Pearson Type III distribution method included in U.S. Water Resources Council guidelines (Reference 195). The resultant curves did not reflect either levee overtopping or levee breaks resulting in extensive areal inundation. Therefore, the shape of the curves was graphically developed to include those conditions. The stage-frequency relationship for each gage was compared with the stage-frequency relationships developed for adjacent gages and, if necessary, adjusted to obtain consistency.

The Sacramento-San Joaquin Delta to the Golden Gate is represented on two grid systems. The coarse grid contains some 250 nodes connected by 325 channels; the fine grid contains 1,200 nodes and 1,800 channels. In addition to physic+ parameters of the individual channels, the model uses inflow, outflow, evaporation losses, tidal elevations, and wind velocity to solve for water-surface elevations.

Higher-high stage-frequency profiles were developed for defined channel reaches by connecting a line between the higher-high stage data for each pertinent gage. It should be noted that a stage shown on the stage-frequency curve for one gage is valid only for that particular gage being analyzed. Synthetic higher-high stage profiles for the 2- and 1-percent annual chance flood and larger events were developed for six main channel reaches within the Delta. The 2- and 1-percent annual chance higher-high stage profiles were based on historical flood profiles and the higher-high stage-frequency curves. The extreme flow and extreme tide combinations were developed using the hydrodynamics model for the Delta area and historical flood profiles. The 1-percent annual chance flood event was extrapolated from a curve developed from 2- and 1-percent annual chance flood data.

<u>City of Pleasant Hill</u>

For the original study, discharge values for Grayson Creek and its tributaries were primarily based on the USGS Central Coast regional regression equations. Significant basin characteristics such as drainage area, mean annual precipitation, and mean basin elevation were included in the discharge computations. Where appropriate, peak discharges were increased to reflect the effects of urbanization within the City of Pleasant Hill. These adjustments were based on the portion of the tributary basin that has been developed and channelized.

The peak discharges used for the Questa portion of the study were obtained from the CCCFCWCD, which developed these discharge values using its own HYDRO-II hydrologic computer program (Reference 26). The peak discharges used for the B&A portion of the study were based on a combination of the USGS regression equations and the discharges developed by the CCCFCWCD.

The CCCFCWCD collects precipitation data and has developed mean seasonal precipitation isohyetal maps and precipitation depth-duration-frequency curves for Contra Costa County. A total of 76 rain gages, maintained by the National Weather Service, the

East Bay Municipal Utility District, and the CCCFCWCD, have been used to develop this information. The CCCFCWCD has adopted a unit hydrograph approach to determine peak runoff conditions that incorporates USACE procedures for developing the unit hydrograph that are very similar to the USACE HEC-1 program (Reference 27). The CCCFCWCD has developed its HYDRO-II program to compute and plot hydrographs, using the relationship between lag time and time rate-of-change of runoff to construct synthetic unit hydrographs. The time rate-of-change of runoff "S" curves, along with infiltration and base flow assumptions, were adopted by the CCCFCWCD using procedures and previous studies conducted by the USACE within the county. HYDRO-II also has routing capabilities. Watershed routing is based on Tatum routing procedures that were adopted by the USACE. On- and off-site detention basins may be routed using the program.

City of Richmond

Unit hydrographs, which represent the response of the basin to runoff-producing rainfall, were derived using the physical characteristics and unit hydrograph relationships, relating time to runoff, which have been developed by the USACE.

Annual maximum peak discharges recorded by U. S. Geological Survey (USGS) stream-gaging stations on streams in or near the study area were tabulated and statistically analyzed using the log-Pearson Type III method as outlined by the Water Resources Council (Reference 40). Streams for which peak flow data was available included Rheem Creek (northeast of Richmond; 37 years of record). Peak discharge-frequency curves, which represent the expected frequency of occurrence of a given discharge, were developed from the record discharges. Due to the short periods of record at the stream-gaging stations near the study area, the 0.2-percent annual chance flood peak discharges, developed from unit hydrograph relationships as mentioned above, were used as a guide in positioning the upper end of each peak discharge-frequency curve. Graphs of these curves do not appear in this report, but were used to develop Frequency-Discharge, Drainage Area Curves.

Tidal flood elevations were determined from extended statistical analyses of annual high tide records. Data were obtained from USGS tidal gaging stations at various locations in the San Francisco-San Pablo Bay areas. The length of record varies from station to station. The log-Pearson Type III method of analysis was used to extract 1- and 0.2-percent annual chance flood elevations from the available natural data. The 0.2-percent annual chance flood elevation was determined as an extrapolation of the Tidal Elevation Frequency Curve.

For the restudy of Rheem Creek, existing hydrology that was developed for the 1974 Flood Insurance Study for the City of Richmond (Reference 176) was used. Rheem Creek was designed to contain 800 cubic feet per second (cfs), which is a 30- year event, at Giant Highway. According to the USACE, Rheem Creek at the Burlington Northern Santa Fe railroad tracks has a drainage area of 1.9 square miles. This includes the San Pablo Tank Farm drainage area of 0.34 square mile. The 1- percent annual chance flood discharge for Rheem Creek at the Burlington Northern Santa Fe railroad tracks is 1,080 cfs.

City of San Pablo

For the Rheem Creek restudy, existing hydrologic data developed for the city's 1977 FIS (Reference 41) were used. Unit hydrographs developed by the USACE, which represent the response of the basin to runoff-producing rainfall, were derived from physical characteristics and unit hydrograph relationships relating time to runoff.

For the restudy of San Pablo and Wildcat Creeks, peak discharge-frequency relationships for the 10-, 2-, 1-, and 0.2-percent annual chance flood events were taken from a report prepared for the USACE, Sacramento District, by WET (Reference 6). Since this study was performed, channel improvements have been completed from the mouth of San Pablo and Wildcat Creeks to the Union Pacific Railroad crossing as described above. The effects of the improvements include backwater effects at the railroad tracks, thus reducing the magnitude of flows diverted from Wildcat Creek to San Pablo Creek. The effects were reflected in the hydraulic analyses performed by the SC along these creeks. Because Wildcat Creek is a smaller watershed, it peaks before San Pablo Creek.

City of San Ramon

Peak discharges were based on a regional regression analysis developed by the study contractor for use in the Contra Costa County Flood Insurance Study (Reference 8). The records of nearby stream gaging stations containing annual flood peaks (Reference 21) were utilized to establish the peak discharge-frequency relationships at the station in accordance with the U.S. Water Resources Council Procedures (Reference 32).

Peak discharges for South San Ramon Creek were determined by the CCCFCWCD using the unit-hydrograph approach. Precipitation loss rates were selected which represent watershed conditions at the time of the study.

City of Walnut Creek

For Walnut Creek, discharges were based in part on analyses of 16 years of record from the Walnut Creek gage No. 11183500 (Reference 21), and 22 years of record from the San Ramon Creek gage No. 11183000. These stream gages are operated by the USGS. The Walnut Creek gage was located approximately one-half mile downstream of the confluence of San Ramon, Las Trampas, and Walnut Creeks; the San Ramon Creek gage is 1.2 miles upstream. The results of these analyses were very similar to discharges previously adopted by the USACE for the Walnut Creek Project (Reference 42) and with the results of regional flood-peak regression equations independently developed by both the USGS (Reference 8) and the study contractor. The USACE 1- and 0.2-percent annual chance flood design flow values for Walnut Creek were adopted for this study.

The flood-peak estimates for the smaller, low-elevation basins of Homestead and East Fork Grayson Creeks are based on the USGS central coast regional-regression equations published in Water Resources Investigation 77-21, Magnitude and Frequency of Floods in California (Reference 8). For the larger hill basins of Walnut, San Ramon, Las Trampas, Tice, and Pine Creeks, the study contractor developed Central-Delta Contra Costa County regional regression equations for use in this study. The results of these equations are consistent with a previously completed Flood Insurance Study (Reference 43) and give very similar results to the USGS equations in these hill drainages. When appropriate, both the USGS and the study contractor estimates were adjusted for the effects of urbanization based on the percentage of the tributary area that was developed and channelized.

The hydrologic analyses for the revised streams were conducted by the CCCFCWCD using their in-house hydrologic program. The county collects precipitation data and has developed mean seasonal precipitation depth-duration-frequency curves for the county. The peak runoffs were determined by a unit hydrograph. This was adopted by the CCCFCWCD and is very similar to the USACE hydrologic computer program HEC-1. The program the CCCFCWCD developed, HYDROII, uses the relationship between lag time and time rate-of-change of runoff to conduct synthetic unit hydrographs.

The peak flows along East Fork Grayson Creek and Eccleston Avenue Tributary were based on USGS Regression Equations (Reference 185). Peak flows for the 10-, 2-, 1-, and 0.2-percent annual chance flood events were determined for East Fork Grayson Creek at cross sections located upstream of Astrid Drive and upstream of the confluence with Eccleston Avenue Tributary. Peak flow for the 1-percent annual chance flood event was determined for Eccleston Avenue Tributary upstream of the confluence with East Fork Grayson Creek. No stream gage records were available for the study stream reaches. The discharges used for this restudy are shown in Table 6, "Summary of Discharges".

Contra Costa County (Unincorporated areas)

Peak discharges for a given stream were developed by various methods. A regional regression analysis developed by the study contractor was the principal method. For all stream in the central delta region of the county (excluding Rodeo, San Pablo, and Walnut Creeks), the records of 16 stream gaging stations containing 278 measured annual flood peaks (Reference 12) were utilized to establish the peak discharge-frequency relationships at the station in accordance with the U.S. Water Resources Council procedures (Reference 192). As there were no stream gages located on the particular stream reaches included in this FIS, the relationships developed at the gaging stations were transferred to the ungaged basins by means of the statistical technique of stepwise multiple regression. The significant basin characteristics were drainage area and mean annual precipitation. Where appropriate, peak discharges were increased to reflect the effects of urbanization. These adjustments were based on that portion of the tributary basin that has been developed and channelized.

Peak discharges developed for Wildcat and lower San Pablo Creeks (Reference 39) agreed acceptably with the regional values and were adopted for this study. USACE design flows for the Walnut Creek Project (Reference 42) and for the Rodeo Creek Project (Reference 193) were adopted for Walnut and Grayson Creeks and for Rodeo Creek, respectively.

The unit hydrograph method was used for Marsh Creek and its tributaries, San and Deer Creeks. Flood hydrographs were developed for the upper reaches of Marsh Creek, routed through the Marsh Creek flood-control reservoir, and summed with the hydrographs developed for the lower reaches.

Stream discharges were reduced by spills from the channel that flowed independently to bypass various stream reaches. Channel spills were particularly large on the lower reaches of San Ramon, Las Trampas, and Marsh Creeks.

The hydraulic regimen of the Sacramento-San Joaquin delta combines two diametrically opposite water movements – Pacific Ocean tidal action and inflow from tributary river basins. Further complicating the hydraulic system are the numerous interconnecting channels and the variability of delta area inflow. The continual interactions of these elements cause a constant change in the water surface throughout the delta area. Tidal action, tributary basin runoff, the meteorologic conditions are the major factors influencing delta area water-surface elevations.

Frequency analyses of water-surface elevations in the delta area were performed using the higher-high stage records of 24 gaging stations located throughout the delta area. The selected period of record for the analyses (1945 to 1974) is subsequent to construction of Shasta Dam on the Sacramento River and covers the maximum length of record for the majority of the gages. Also, the delta area hydraulic pattern has not changed significantly during that period.

Originally, the stage data were statistically analyzed using the log Pearson Type III distribution method included in U.S. Water Resources Council guidelines (Reference 192). The resultant curves did not reflect either levee overtopping or levee breaks resulting in extensive areal inundation. Therefore, the shape of the curves was graphically developed to include those conditions. The stage-frequency relationship for each gage was compared with the stage-frequency relationships developed for adjacent gages and, if necessary, adjusted to obtain consistency.

The Tidal Hydrodynamics Model (a mathematical computer program developed by the California Department of Water Resources), which incorporates a link-node concept to simulate a general estuarine environment of channels and embayments, was used during this study to analyze extreme flow and tide events (larger than a 1-percent annual chance flood). The mean daily inflow to the delta area from tributary river basins during six of the largest floods in the area and the corresponding Golden Gate tidal data were input to the model. A comparison of the computed results from the model with the recorded tidal stages for each of the six floods proved satisfactory.

Higher-high stage-frequency profiles were developed for defined channel reaches by connecting a line between the higher-high stage data for each pertinent gage. It should be noted that a stage shown on the stage-frequency curve for one gage is valid only for that particular gage being analyzed. Synthetic higher-high stage profiles for the 2- and 1-percent annual chance floods and larger events were developed for six main channel reaches within the Delta. The 2- and 1-percent annual chance flood high higher-high stage profiles were based on historical flood profiles and the higher-high stage-frequency curves. The extreme flow and extreme tide combinations were developed using the Delta Hydrodynamics Model and historical flood profiles. The 10-percent annual chance flood event was extrapolated from a curve developed from 2- and 1-percent annual chance flood data.

The analysis used in this study reflects a static water condition, which includes a combination of river inflow, tidal effect, and wind set.

The hydrologic analyses for the revised streams were conducted by the CCCFCWCD using their in-house hydrologic program. The county collects precipitation data and has developed mean seasonal precipitation depth-duration-frequency curves for the county. The peak runoffs were determined by a unit hydrograph. This was adopted by the CCCFCWCD and is very similar to the USACE hydrologic computer program HEC-1. The program that the CCCFCWCD developed, HYDRO-II, uses the relationship between lag time and time rate-of change of runoff to conduct synthetic unit hydrographs.

A second study was revised on September 7, 2001, to incorporate detailed flood hazard information along:

> Mitchell Creek from its confluence with Mount Diablo Creek, located in the City of Clayton, California, to a point approximately 2,150 feet (0.41 mile) upstream of Diablo Downs Road;
>
> Mount Diablo Creek from a point approximately 2,675 feet downstream of Bailey Road to a point approximately 35 feet downstream of Russelmann Park Road;
>
> Green Valley Creek from the upstream end of the Interstate 680 culvert, located in the Town of Danville, California, to a point approximately 4,424 feet (0.84 mile) upstream of Stone Valley Road;
>
> Rodeo Creek from its confluence with San Pablo Bay to a point approximately 425 feet upstream of Hawthorne Drive;
>
> Garrity Creek from approximately 350 feet downstream of Union Pacific Railroad to a point approximately 165 feet upstream of Brian Road;
>
> Grayson Creek from approximately 1,890 feet downstream of Interstate 680 to the confluence of East Fork Grayson Creek and West Fork Grayson Creek, located in the City of Pleasant Hill, California;
>
> Appian Creek from its confluence with San Pablo Creek, located in the City of Richmond, California, to a point approximately 2,965 feet (0.56 mile) upstream of Appian Way;
>
> Arroyo del Hambra Creek from John Muir Parkway, located in the City of Martinez, California, to a point approximately 2,858 feet (0.54) mile upstream of Alhambra Avenue;

West Alamo Creek from a point approximately 2,870 feet (0.54 mile) downstream of Green Meadow Drive to the upstream side of Blackhawk Meadow Drive;

Wildcat Creek from its mouth to a point approximately 70 feet upstream of Vale Road, located in the City of San Pablo, California;

San Pablo Creek from its mouth to a point approximately 1,000 feet upstream of Church Lane, located in the City of San Pablo, California;

Line A, DA-40 from a point approximately 80 feet upstream of Pacheco Boulevard, located in the City of Martinez, California, to a point approximately 2,410 feet (0.46 mile) upstream of Howe Road.

In addition, Sinks 290-300 were studied by approximate methods.

For this restudy, peak discharge-frequency relationships for the 10-, 2-, 1- and 0.2-percent annual chance flood events for San Pablo and Wildcat Creeks were taken from a report prepared for the USACE, Sacramento District by WET (Reference 6). Since this study was performed, channel improvements have been completed from the mouth of San Pablo and Wildcat Creeks to the Union Pacific Railroad crossing as described above. The effect of the improvements has reduced backwater effects at the railroad tracks, thus reducing the magnitude of flows diverted from Wildcat Creek to San Pablo Creek, which was reflected in the hydraulic analyses performed by the study contractor along these creeks. It should be noted that Wildcat Creek, due to its smaller watershed, peaks before San Pablo Creek.

The peak discharges used for the remaining streams studied by detailed methods as part of this restudy were obtained from CCCFCWCD who developed these discharge values using their HYDRO-II hydrologic computer program (Reference 26).

CCCFCWCD collects precipitation data and has developed mean seasonal precipitation isohyetal maps and precipitation depth-duration-frequency curves for Contra Costa County. A total of 76 rain gages, which are maintained by the National Weather Service, the East Bay Municipal Utility District and CCCFCWCD, have been used to develop this information. CCCFCWCD has adopted a unit hydrograph approach to determine peak runoff conditions which incorporate USACE procedures for developing the unit hydrograph which are very similar to the USACE program HEC-1 (Reference 38). CCCFCWCD has developed their HYDRO-II program to compute and plot hydrographs. This program uses the relationship between lag time and time rate-of-change of runoff to construct synthetic unit hydrographs. The time rate of change of runoff "S" curves, as well as infiltration and base flow assumptions, were adopted by CCCFCWCD utilizing procedures and previous studies conducted by USACE within the county. HYDRO-II also has routing capabilities. Watershed routing is based on Tatum routing procedures that were adopted by USACE. On- and off-site detention basins may be routed using the program.

The 10-, 2-, 1-, and 0.2-percent annual chance peak flows along Murderers Creek were developed using USGS regression equations (Reference 118). Peak flows for the 10-, 2-, 1-, and 0.2-percent annual chance flood events were determined for Murderers Creek at cross sections located upstream of the confluence with East Fork Grayson Creek, upstream of Roberta Avenue, upstream of Oak Park Boulevard, upstream of Tributary A, and upstream of Tributary B within the City of Pleasant Hill. No stream gage records were available for the study stream reaches.

A summary of the drainage area-peak discharge relationships for the streams studied by detailed methods is shown in Table 6, "Summary of Discharges."

Table 6: Summary of Discharges

Flooding Source and Location	Drainage Area (sq mi)	Peak Discharges (cfs) 10-Percent Annual Chance	2-Percent Annual Chance	1-Percent Annual Chance	0.2-Percent Annual Chance
APPIAN CREEK					
Approximately 1,950 feet upstream of Appian Way	0.60	320	450	490	580
At Appian Way	0.86	430	600	660	780
At confluence with San Pablo Creek	0.98	450	640	710	840
ARROYO DEL HAMBRA CREEK					
At John Muir Parkway	8.97	1,788[1]	2,413[1]	2,660[1]	2,903[1]
At Jose Lane	7.10	2,240	3,290	3,660	4,380
BRUSHY CREEK					
Just Downstream of Vasco Road	8.85	1,630	3,030	3,560	4,560
Downstream of Breakout 1 (Approximately 1.1 mile downstream of Vasco Road)	10.14	840	1,240	1,410	1,700
Approximately 1.0 mile upstream of Falcon Way	10.26	840	1,270	1,620	2,300
Downstream of Breakout 2 (Approximately 900 feet upstream of Falcon Way)	10.37	370	670	920	1,410
Approximately 1,200 feet upstream of Byron Hot Springs Road	14.75	560	1,140	1,450	2,420
BRUSHY CREEK – BREAKOUT 1					
Just downstream of divergence from Brushy Creek	[2]	790	1,790	2,150	2,860
Just downstream of confluence with Brushy Creek Breakout 2	[2]	1,260	2,390	2,850	3,750
BRUSHY CREEK – BREAKOUT 2					
Just downstream of divergence from Brushy Creek	[2]	470	600	700	890
BROOKSIDE ROAD TRIBUTARY	0.95	[3]	[3]	925	[3]
CASCADE CREEK					
At San Pablo Creek confluence	0.60	185	325	360	470

[1] *Increase in area with decrease in flow is result of spill*

[2] *Drainage area not available*

[3] *Data not computed*

Table 6 Summary of Discharges, continued

Flooding Source and Location	Drainage Area (sq mi)	Peak Discharges (cfs) Flooding Source and Location	Drainage Area (sq mi)	Flooding Source and Location	Drainage Area (sq mi)
CLAYTON VALLEY DRAIN					
1,135 feet upstream of Salvio Street	2.10	480	790	930	1,200
At confluence with Walnut Creek	4.40	1,200	1,800	2,100	2,400
CORLISS DRIVE TRIBUTARY					
At confluence with Laguna Creek	0.40	160	250	280	300
DEER CREEK					
At Marsh Creek confluence	6.40	170[1]	880	1,200	1,800
11,320 feet upstream of confluence	5.43	[2]	[2]	571	[2]
14,100 feet upstream of confluence	4.88	[2]	[2]	317	[2]
DITCH NO. 2					
At Bart Culvert	2.10	900	1,300	1,450	1,650
At confluence with Pine Creek	3.30	1,100	1,500	1,700	2,000
DONNER CREEK					
At confluence with Mount Diablo	2.90	845	1,250	1,390	1,680
Creek					
At Marsh Creek Road	2.90	380	740	880	1,400
DOW CHANNEL	[3]	470	1,020	1,120	1,120
EAST ANTIOCH CREEK					
At East 18th Street	5.80	340	610	760	1,900
EAST BRANCH GREEN VALLEY CREEK					
At Green Valley Road	5.00	630	1,260	1,550	2,290
EAST BRANCH REFUGIO CREEK					
At confluence with Refugio Creek	0.70	200	250	260	280
At Willow Avenue	0.50	200	240	260	260

[1] *Flows reduced by reservoir routing*

[2] *Data not computed*

[3] *Peaks reduced due to bypassing and/or nonreturning overbank spills*

Table 6 Summary of Discharges, continued

Flooding Source and Location	Drainage Area (sq mi)	Peak Discharges (cfs) 10-Percent Annual Chance	2-Percent Annual Chance	1-Percent Annual Chance	0.2-Percent Annual Chance
EAST FORK GRAYSON CREEK					
At Astrid Drive	1.93	850	1,220	1,330	1,600
Just upstream of confluence with Murderers Creek	2.54	1,040	1,490	1,640	2,100
Just upstream of confluence with West Fork Grayson Creek	7.13	1,980	2,880	3,180	3,810
Just upstream of Eccleston Avenue Tributary	0.91	450	670	760	1,000
Upstream of Oak Park Boulevard	[1]	850	1,207	1,304[2]	1,394[2]
FARM BUREAU ROAD DRAIN					
At confluence with Contra Costa Canal	1.40	290	510	610	800
FLAME DRIVE CREEK					
Upstream of confluence with Grayson Creek	1.00	270[3]	430	500	620
FRISK CREEK[1]					
Just downstream of Byron Highway	6.44	590	1,240	1,500	1,990
Approximately 2,000 feet downstream of Camino Diablo Road	11.36	665	925	1000	1300
GALINDO CREEK					
Approximately 2,500 feet downstream of Newhall Parkway	4.73	1,200	1,790	1,990	2,400
At Contra Costa Canal	7.73	1,580	2,330	2,570	3,100
At Cowell Road	6.33	1,400	2,050	2,270	2,740
At Newhall Parkway	3.56	900	1,360	1,510	1,830

[1]*Flows decrease moving downstream due to storage*

[2]*Flows in the main channel under the influence of split flows*

[3]*Discharge does not consider reduction due to upstream storage*

Table 6 Summary of Discharges, continued

Flooding Source and Location	Drainage Area (sq mi)	Peak Discharges (cfs) 10-Percent Annual Chance	2-Percent Annual Chance	1-Percent Annual Chance	0.2-Percent Annual Chance
GALINDO CREEK, continued					
At San Miguel Road	8.00	1,580	2,330	2,570	3,100
At Treat Boulevard	5.52	1,290	1,930	2,140	2,590
GARRITY CREEK					
At Union Pacific Railroad	3.19	1,010	1,420	1,570	1,860
At upstream side of San Pablo Avenue	1.99	645	910	1,000	1,190
GRAYSON CREEK					
At State Highway 4	16.26	3,230	4,800	5,320	6,420
Downstream of confluence with West Fork Grayson Creek	12.48	3,150	4,650	5,150	6,200
GREEN VALLEY CREEK					
At Diablo Road	7.76	2,180	3,210	3,550	4,270
At Interstate 680	9.21	2,490	3,650	4,040	4,850
Downstream of confluence with East Branch Green Valley Creek	7.59	2,150	2,170	3,510	4,230
Upstream of confluence with East Branch Green Valley Creek	2.53	865	1,260	1,400	1,680
GRIZZLY CREEK					
At confluence with Las Trampas Creek	1.90	400	740	850	1,170
HAPPY VALLEY CREEK					
At Happy Valley Road	1.80	480	830	950	1,200
At State Highway 24	2.30	600	1,070	1,230	1,580
HIDDEN VALLEY CREEK					
At corporate limits	0.20	80	130	140	170
At El Nido Ranch Road	1.80	600	1,020	1,120	1,400
IVY DRIVE TRIBUTARY					
At confluence with Moraga Creek	0.50	170	280	310	360
JONAS HILL CREEK					
At Monroe Avenue	1.00	310	540	590	730
KELLOGG CREEK					
Just downstream of Vasco Road	27.43	1,120	2,250	3,690	3,540

Table 6 Summary of Discharges, continued

Flooding Source and Location	Drainage Area (sq mi)	Peak Discharges (cfs) 10-Percent Annual Chance	2-Percent Annual Chance	1-Percent Annual Chance	0.2-Percent Annual Chance
KELLOGG CREEK, continued					
Just upstream of the divergence of Kellogg Creek Split Flow	[1]	1,100	2,320	2,810	3,760
Just downstream of the divergence of Kellogg Creek Split Flow	[1]	388	1,134	1,278	2,200
Just downstream of the confluence with Kellogg Creek Split Flow	[1]	1,120	2,390	2,910	2,890
Just upstream of Bixler Road	[1]	700[2]	1,200[2]	1,274[2]	2,000[2]
KELLOGG CREEK SPLIT					
At the divergence from Kellogg Creek	[1]	709	1,180	1,236	1,564
KIRKER CREEK					
At Buchanan Road	7.31	1,154	1,672	1,757	2,040
At Dow Channel	12.7	1,254[3]	1,360[3]	1,380[3]	1,400[3]
At Los Medanos Wasteway	8.20	630	1,300	1,670	2,900
At Standard Oil Avenue	12.70	470[3]	1,350[3]	1,500[3]	1,500[3]
(Below Loveridge Road)					
Downstream of State Highway 4	10.90	1,017[3]	1,822[3]	2,539[3]	2,539[3]
Upstream of State Highway 4	10.90	780	1,660	2,100	3,700
At State Highway 4	9.03	1,396	2,031	2,168	2,468
At Contra Costa Canal	7.31	1,154	1,672	1,757	2,040
Upstream of Brush Creek Drive	5.64	1,217	2,139	2,457	3,057
KIRKER CREEK BYPASS	[1]	576	795	971	1,095
LAFAYETTE CREEK					
At Moraga Road	2.90	800	1,520	1,740	2,200
At Third Street	5.60	1,500	2,700	3,100	4,000
LAGUNA CREEK					
At confluence with Moraga Creek	3.80	1,040	1,800	2,100	2,300
At Corliss Drive	2.40	660	1,100	1,300	1,500
At Rheem Boulevard	1.50	450	750	850	960
LARCH CREEK					
At Larch Avenue	0.30	80	140	150	200

[1] *Drainage area not available*

[2] *Flows decrease moving downstream due to storage*

[3] *Peaks reduced due to bypassing and/or nonreturning overbank spills*

Table 6 Summary of Discharges, continued

Flooding Source and Location	Drainage Area (sq mi)	Peak Discharges (cfs) 10-Percent Annual Chance	2-Percent Annual Chance	1-Percent Annual Chance	0.2-Percent Annual Chance
LAS TRAMPAS CREEK					
At corporate limits	2.60	580	1,080	1,240	1,630
At Fourth Street	15.10	3,300	6,200	7,000	9,000
At Freeman Road	20.00	4,650	6,870	7,650	9,180
At Paradise Court	8.50	1,560	3,000	3,600	4,800
At San Ramon Creek	27.05	5,410	8,090	9,000	10,800
At St. Marys Road	3.20	700	1,300	1,500	1,900
At Tice Creek	22.76	4,650	6,870	7,650	9,180
Upstream of Grizzly Creek confluence	5.30	1,100	2,100	2,400	3,200
LAUTERWASSER CREEK					
At San Pablo Creek confluence	2.60	620	1,140	1,300	1,700
LAWLOR CREEK					
At Pittsburg	1.10	170	260	310	460
At railroad	1.80	190	370	460	700
LINE A, DA-40					
At Pacheco Boulevard	1.47	605	860	945	1,130
LOS MEDANOS WASTEWAY					
Above Dow Channel	[1]	70	110	290	570
MANGINI CREEK					
At Apollo Way	2.20	530	840	970	1,200
MARSH CREEK					
At Concord Boulevard	52.67	520	580	620	720
At Balfour Road	58.22	890	1,250	1,400	1,650
At Central Avenue	65.05	950	1,350	1,500	1,780
At Union Pacific Railroad	81.01	1,650	2,500	2,820	3,400
At Delta Road	85.74	2,110	3,330	3,810	4,680
At Santa Fe Railroad	88.99	2,370	3,780	4,340	5,360
MCCOLLUM CREEK					
Upstream of confluence with Grayson Creek	0.40	150	220	250	300
MIRANDA CREEK					
At U.S. Interstate 680	2.40	340	620	75	1,000
MITCHELL CREEK					
At confluence with Mount Diablo Creek	4.50	1,090	1,630	1,810	2,190

[1]*Drainage area not available*

Table 6 Summary of Discharges, continued

Flooding Source and Location	Drainage Area (sq mi)	Peak Discharges (cfs) 10-Percent Annual Chance	2-Percent Annual Chance	1-Percent Annual Chance	0.2-Percent Annual Chance
MORAGA CREEK					
At confluence with Laguna Creek	7.00	1,790	3,300	3,800	4,300
At corporate limits (Ivy Drive)	2.00	540	980	1,100	1,440
At upper San Leandro Reservoir	9.90	2,300	4,300	5,000	5,900
MOUNT DIABLO CREEK					
Downstream of Bailey Road (Downstream of Naval Base Breakout)	1	1,547	1,547	1,560	1,654
Approximately 3,000 feet downstream of Bailey Road	1	2,172	2,572	2,777	3,270
Approximately 3,300 feet downstream of Bailey Road	1	2,207	2,647	2,791	3,138
Approximately 1.1 miles downstream of Bailey Road	1	2,893	3,789	4,046	4,602
Downstream Sutherland Drive Breakout (Approximately 300 feet downstream of Ayers Road)	1	3,451	5,247	5,701	6,741
Approximately 600 feet upstream of Concord Boulevard	1	3,661	5,517	6,111	7,252
Downstream of Bailey Road	21.83	3,670	5,670	6,350	7,760
Upstream of Bailey Road	1	3,671	5,677	6,191	7,371
Downstream of State Highway 4	1	3,813	5,573	6,154	7,547
Approximately 1,800 feet upstream of BNSF Railroad		4,296	6,451	7,208	9,005
MOUNT DIABLO SPLIT AT SUTHERLAND DRIVE					
Along Sutherland Drive	1	0	94	160	389
MOUNT DIABLO SPLIT AT HEATHER DRIVE					
At breakout from Mt. Diablo Creek	1	0	311	559	1,107
Downstream of Bonwell Drive	1	0	404	718	1,494
MOUNT DIABLO SPLIT AT NAVAL BASE					
Total Divergence from Mt. Diablo Creek	1	2,003	3,878	4,596	6,039
MURDERERS CREEK					
At Oak Park Boulevard	2.22	570	940	1,120	1,600

[1]*Drainage area not available*

Table 6 Summary of Discharges, continued

Flooding Source and Location	Drainage Area (sq mi)	Peak Discharges (cfs) 10-Percent Annual Chance	2-Percent Annual Chance	1-Percent Annual Chance	0.2-Percent Annual Chance
MURDERERS CREEK, continued					
Upstream of confluence with East Fork Grayson Creek	3.21	1,020	1,570	1,850[1]	2,650
Upstream of confluence with Tributary A	1.60	400	690	820	1,200
Upstream of confluence with Tributary B	0.91	40	410	500	710
NORTH BRANCH RELIEZ CREEK					
At mouth	0.20	60	100	110	150
NORTH BRANCH STONE VALLEY CREEK					
At Austin Lane	0.70	160	250	300	340
OLD KIRKER CREEK					
Below Dow Channel	[2]	0	330	380	380
OVERHILL CREEK					
At Moraga Way	0.40	130	225	250	320
PACHECO CREEK					
At gaging station in Walnut Creek	77.20	9,500	18,000	22,000	31,000
At Union Pacific Railroad	[2]	[3]	[3]	[3]	[3]
Near Suisun Bay	141.00	11,000	20,500	25,000	35,000
PAYTON SLOUGH					
Above U.S. Interstate 680	1.80	370	620	750	1,000
PINE CREEK					
At confluence with Contra Costa Canal	13.80	980	2,200	2,800	4,400
At confluence with Walnut Creek	29.10	3,200	6,000	7,300	10,000
At Monument Boulevard	19.40	1,700	3,400	4,300	6,400
PINOLE CREEK					
At corporate limits	10.70	1,280	1,810	1,960	2,200
At Interstate Highway 80	13.90	1,460	2,070	2,240	2,500
At San Pablo Bay	15.00	1,520	2,150	2,320	2,600

[1]*Includes split flows*

[2]*Drainage area not available*

[3]*Data not computed*

Table 6 Summary of Discharges, continued

Flooding Source and Location	Drainage Area (sq mi)	Peak Discharges (cfs) 10-Percent Annual Chance	2-Percent Annual Chance	1-Percent Annual Chance	0.2-Percent Annual Chance
REFUGIO CREEK					
At Hercules Corporate Limits	1.10	220	290	320	350
At San Pablo Bay	4.50	680	990	1,120	1,400
At Sycamore Road	2.20	420	558	595	668
RELIEZ CREEK					
At Springhill Court	0.90	200	350	400	560
Upstream of Condit Road	3.38	1,040	1,535	1,685	2,200[1]
Upstream of Highway 24	3.14	965	1,430	1,570	2,050[1]
Upstream of Pleasant Hill Road	2.34	720	1,065	1,170	1,500[1]
Upstream of Stanley Boulevard	2.66	820	1,210	1,330	1,800[1]
RODEO CREEK					
At Diablo Road	9.77	1,710	2,590	2,900	3,510
At San Pablo Bay	10.40	1,760	2,660	2,960	3,590
SAND CREEK					
At Marsh Creek confluence	14.00	1,000	2,300	2,900	4,500
SAN PABLO CREEK					
2,000 feet upstream of Orinda Way	7.50	[2]	[2]	5,040	[2]
At Bear Creek Road	13.70	3,000	5,700	6,700	8,700
At Church Lane	39.00	2,250	4,000	5,100	7,550
At confluence with Brookside Road Tributary to Orchard Road	1.80	[2]	[2]	1,470	[3]
At mouth	40.00	2,450	3,920[1]	4,320[1]	4,680[1]
Downstream of West Branch (at Brookwood Road)	6.60	[2]	[2]	4,550	[2]
Glorietta Road to Greenwood Court	0.47	[2]	[2]	445	[2]
Orchard Road to Glorietta Road	1.19	[2]	[2]	1,120	[2]
Upstream of Brookwood Road	3.60	[2]	[2]	2,550	[2]
(West Branch)					[2]
Upstream of Camino Encinatas	3.20	[2]	[2]	2,250	[2]
Upstream of Greenwood Court	0.14	[2]	[2]	175	[2]
Upstream of Orinda Way	8.20	[2]	[2]	5,270	[2]

[1]*0.2-percent annual chance floodflow projected using the Drainage Master Plan*

[2]*Data not computed*

[3]*Flows decrease due to the effects of San Ramon Bypass*

Table 6 Summary of Discharges, continued

Flooding Source and Location	Drainage Area (sq mi)	Peak Discharges (cfs) Flooding Source and Location	Drainage Area (sq mi)	Flooding Source and Location	Drainage Area (sq mi)
SAN RAMON CREEK					
At La Gonda Way	33.1	3,100	6,800	8,300	13,000
At Las Trampas Creek	51.17	330[1]	380[1]	500[1]	1,440[1]
At Miranda Creek	46.31	6,800	10,500	11,800	14,400
At San Crainte Creek	47.90	7,620	11,800	13,200	16,100
At San Ramon Valley Boulevard	8.50	1,400	2,700	3,200	4,400
Below Sycamore Creek confluence	20.3	2,200	4,600	5,600	8,500
SAN RAMON BYPASS					
At junction of Old Channel	50.90	7,820	12,000	13,400	16,300
At San Crainte Creek	47.90	7,620	11,800	13,200	16,100
SANS CRAINTE CREEK					
At Milton Avenue	1.40	430	635	705	850
At Palmer Road	1.29	420	615	680	820
Downstream of San Miguel Avenue	2.60	780	1,160	1,290	1,350
Upstream of Palmer Road Main Branch	1.03	320	470	520	630
SOUTH BRANCH MORAGA CREEK					
At confluence with Moraga Creek	2.10	500	920	1,050	1,360
At corporate limits	1.20	320	570	640	830
SOUTH SAN RAMON CREEK					
At Alcosta Boulevard	11.20	2,650	3,920	4,350	5,300
Below Channel Z	5.90	2,180	3,020	3,290	4,050
Below Norris Creek	8.30	2,300	3,380	3,750	4,600
ST. MARYS ROAD TRIBUTARY					
At confluence with Laguna Creek	0.80	260	420	480	520
STONE VALLEY CREEK					
At U.S. Interstate 680	2.60	310	610	730	1,200
SUMMER LAKE					
Approximately 2,600 feet southeast of the intersection of Cypress Road and Bethel Island Road	0.52	---[2]	---[2]	610	---[2]

[1]*Flows decrease due to the effects of San Ramon Bypass*

[2]*Data not computed*

Table 6 Summary of Discharges, continued

Flooding Source and Location	Drainage Area (sq mi)	Peak Discharges (cfs) 10-Percent Annual Chance	2-Percent Annual Chance	1-Percent Annual Chance	0.2-Percent Annual Chance
SYCAMORE CREEK					
At Camino Tassajara	4.80	500	1,000	1,200	1,900
At Morninghome Road	8.20	750	1,660	1,900	3,100
TICE CREEK					
At Castle Glen Tributary	3.14	700	1,170	1,470	1,730
At Las Trampas Creek	4.06	860	1,470	1,770	2,290
WALNUT CREEK					
At corporate limits at State Highway 4 (Arnold Industrial Highway)	117.30	9,520	18,000	22,300	31,000
At San Ramon Bypass	27.78	5,740	8,470	9,510	12,300
At Walnut Creek Stream Gage (upstream of Concord)	77.20	9,520	17,700	22,000	30,600
WEST ALAMO CREEK					
Approximately 4,000 feet upstream of Tassajara Road	2.62	740	1,100	1,230	1,480
Approximately 6,000 feet upstream of Tassajara Road	2.17	600	895	995	1,210
Inflow to Bettencourt Basin at Tassajara Road	3.13	800	1,200	1,340	1,630
WEST ANTIOCH CREEK					
At fairgrounds	8.60	790	1,580	2,000	2,900
WEST BRANCH REFUGIO CREEK					
At confluence with Refugio Creek	0.70	150	200	210	240
At Hercules corporate limits	0.20	50	70	75	85
WEST FORK GRAYSON CREEK					
At Oak Park Boulevard	2.00	340	610	730	990
Upstream of confluence with East Fork Grayson Creek	4.50	1,170	1,770	1,970	2,390
WILDCAT CREEK					
At Church Lane	8.00	1,250	1,950	2,300	2,600
At mouth	9.00	1,020[1]	1,180[1]	1,260[1]	1,330[1]
WILLOW CREEK					
Just upstream of Cape May Drive	0.01	[2]	[2]	249	[2]
Approximately 450 feet upstream of Nantucket Drive	0.03	[2]	[2]	278	[2]

[1] *Increase in area with decrease in flow is result of spill*

[2] *Data not computed*

Elevations for the 10-, 1-, and 0.2-percent annual chance flood event tides for the portion of San Pablo Bay east of Highway 160 were taken from a USACE study (Reference 177). Tides for selected recurrence intervals are shown in Table 7, "Summary of Elevations."

Table 7: Summary of Elevations

Flooding Location	Elevations (Feet, NAVD)			
	10-Percent Annual Chance	**2-Percent Annual Chance**	**1-Percent Annual Chance**	**0.2-Percent Annual Chance**
SAN JOAQUIN RIVER				
At Byron Tract	8.7	9.6	9.9	10.3
At Holland Tract	8.3	9.2	9.5	10.0
At Marsh Creek	8.1	8.8	9.0	9.3
At Webb Tract	8.4	9.1	9.4	9.8
SUMMER LAKE				
Approximately 2,600 feet southeast of the intersection of Cypress Road and Bethel Island Road	---[1]	---[1]	-6	---[1]
UPPER SAN LEANDRO RESERVOIR				
Southwest of the Town of Moraga	467.8	469.3	469.9	471.3

[1]*Data not computed*