FLOOD INSURANCE STUDY

VOLUME 1 OF 3

MARIN COUNTY, CALIFORNIA
AND INCORPORATED AREAS

COMMUNITY NAME	COMMUNITY NUMBER
BELVEDERE, CITY OF	060429
CORTE MADERA, TOWN OF	065023
FAIRFAX, TOWN OF	060175
LARKSPUR, CITY OF	065040
MARIN COUNTY (UNINCORPORATED AREAS)	060173
MILL VALLEY, CITY OF	060177
NOVATO, CITY OF	060178
ROSS, TOWN OF	060179
SAN ANSELMO, TOWN OF	060180
SAN RAFAEL, CITY OF	065058
SAUSALITO, CITY OF	060182
TIBURON, TOWN OF	060430

PRELIMINARY

MAR 24 2014

REVISED
<date>

Federal Emergency Management Agency

FLOOD INSURANCE STUDY NUMBER
06041CV001C

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.

This FIS report was revised on <date>. Users should refer to Section 10.0, Revisions Description, for further information. Section 10.0 is intended to present the most up-to-date information for specific portions of this FIS report. Therefore, users of this FIS report should be aware that the information presented in Section 10.0 supersedes information in Sections 1.0 through 9.0 of this FIS report.

Initial Countywide FIS Effective Date:	May 4, 2009	
Revised Countywide FIS Date:	March 17, 2014	First Revision
	<date>	Second Revision

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Exhibit 1 - FLOOD PROFILES

FLOOD INSURANCE STUDY
MARIN COUNTY, CALIFORNIA AND INCORPORATED AREAS

1.0 INTRODUCTION

1.1 Purpose of Study

This Flood Insurance Study (FIS) revises and supersedes the FIS reports and/or Flood Insurance Rate Maps (FIRMs) in the geographic area of Marin County, California, including the Cities of Belvedere, Larkspur, Mill Valley, Novato, San Rafael, Sausalito, and the Towns of Corte Madera, Fairfax, San Anselmo, Ross, and Tiburon, and the unincorporated areas of Marin County (hereinafter referred to collectively as Marin County), and aids in the administration of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. This study has developed flood risk data for various areas of the community that will be used to establish actuarial flood insurance rates. This information will also be used by Marin County to update existing floodplain regulations as part of the Regular Phase of the National Flood Insurance Program (NFIP), and by local and regional planners to further promote sound land use and floodplain development. 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.

The Digital Flood Insurance Rate Map (DFIRM) and FIS Report for this countywide study have been produced in digital format. Flood hazard information was converted to meet the Federal Emergency Management Agency (FEMA) DFIRM database specifications and Geographic Information and is provided in a digital format so that it can be incorporated into a local GIS and be accessed more easily by the community.

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.

Information on the authority and acknowledgments for each of the previously identified FIS reports and FIRMs for communities within Marin County was compiled from their previously printed FIS reports and is shown below.

Belvedere, City of:	The hydrologic and hydraulic analyses from an unpublished FIS report dated February 1975 were performed by the U.S. Geological Survey (USGS) for the Federal Insurance Administration (FIA) under Inter-Agency

Agreement No. IAA-H-3-73, Project Order No. 8. That work was completed in May 1974.

Corte Madera, Town of:	The hydrologic and hydraulic analyses from the FIS report dated March 1977 were performed by the U.S. Geological Survey (USGS), California District, Water Resources Division, for the Federal Insurance Administration (FIA) under Inter-Agency Agreement No. IAA-H-19-71, Project Order No. 2. That work, which was completed in March 1975, covered all significant flooding sources affecting the Town of Corte Madera.
Fairfax, Town of:	The hydrologic and hydraulic analyses from the FIS report dated March 1977 were performed by the USGS, for the FIA, under Inter-Agency Agreement No. IAA-H-17-75, Project Order No. 12. That work, which was completed in June 1976, covered all significant flooding sources affecting the Town of Fairfax.
Larkspur, City of:	The hydrologic and hydraulic analyses from the FIS report dated September 15, 1983, were performed by George S. Nolte and Associates, for the Federal Emergency Management Agency (FEMA), under Contract No. H-4722. That study was completed in December 1982.
Marin County (Unincorporated Areas):	The hydrologic and hydraulic analyses from the FIS report dated May 5, 1997, were performed by the USACE, for FEMA, under Inter-Agency Agreement No. IAA-H-10-77, Project Order No. 5, Amendment 5. That study was completed in November 1979.
Marin County (Countywide)	Hydrologic and hydraulic analyses from the FIS report dated May 4, 2009, were performed by MAPIX Mainland for FEMA.
Mill Valley, City of:	The hydrologic and hydraulic analyses from the FIS report dated July 1978 were performed by the U.S. Army Corps of Engineers (USACE), San Francisco District, for the FIA, under Inter-Agency Agreement Nos. IAA-H-2-73, IAA-H-19-74, and IAA-H-16-75, Project Order Nos. 2, 18, and 22, respectively. That work, which was

completed in December 1975, covered all flooding sources affecting the City of Mill Valley.

Novato, City of: The hydrologic and hydraulic analyses from the FIS report dated September 29, 1989, were performed by the USACE, San Francisco District, for FEMA, under Inter-Agency Agreement No. IAA-H-19-74, Project Order Nos. 17 and 23, and Inter-Agency Agreement No. IAA-H-16-75, Project Order No. 22. That work, which was completed in May 1976, covered all significant flooding sources affecting the City of Novato.

Subsequent to the original study, the FIRM, the Flood Boundary and Floodway Map (FBFM), and FIS for the City of Novato were revised to add and modify zones and base flood elevations due to annexations along Novato Creek, Vineyard Creek, Wilson Creek, Arroyo San Jose, and Pacheco Creek. Tidal flooding was added along the eastern corporate limits. The maps were also revised to include all flooding sources within Hamilton Air Force Base.

A restudy, dated September 29, 1989, was conducted by the USACE, San Francisco District, at the request of FEMA under Inter-Agency Agreement No. EMW-84-E-1506, Project Order No. 1, Amendment No. 12. That work was completed in December 1987.

All survey and topographic data were obtained by the San Francisco District from its own records, from the Marin County Flood Control and Water Conservation District, the City of Novato Department of Community Development and the State of California Department of Transportation.

Ross, Town of: The hydrologic and hydraulic analyses from the FIS report dated August 4, 1980, were performed by the USGS, for the FIA, under Inter-Agency Agreement No. IAA-H-17-75, Project Order No. 12. That work, which was completed in October 1979, covered all significant flooding sources affecting the Town of Ross.

San Anselmo, Town of:	The hydrologic and hydraulic analyses from the FIS report dated February 1977 were performed by the USGS for the FIA, under Inter-Agency Agreement No. IAA-H-17-75, Project Order No. 12. That work, which was completed in June 1976, covered all significant flooding sources affecting the Town of San Anselmo.
San Rafael, City of:	The hydrologic and hydraulic analyses from the FIS report dated January 3, 1997, were performed by George S. Nolte and Associates, for FEMA, under Contract No. H-4722. That study was completed in December 1982. A subsequent study was revised on May 5, 1997, to show modifications to the flooding along Miller Creek from U.S. Highway 101 to the Southern Pacific Railroad. The hydrologic and hydraulic analyses for this revision were performed for FEMA by Ensign & Buckley, Consulting Engineers, under Contract No. EMW-90-C-3133.
Sausalito, City of:	The hydrologic and hydraulic analyses from the FIS report dated March 1980 were performed by the USGS, for the FIA, under Inter-Agency Agreement No. IAA-H-17-75, Project Order No. 12. That work, which was completed in May 1979, covered all significant flooding sources affecting the City of Sausalito.
Tiburon, Town of:	The hydrologic and hydraulic analyses from the FIS report dated November 1976 were performed by the USGS, Water Resources Division, California District, Menlo Park, California, for the FIA, under Inter-Agency Agreement No. IAA-H-3-74, Project Order No. 8. That work, which was completed in December 1974, covered all flooding sources affecting the Town of Tiburon.

For this revision to the countywide FIS report, detailed coastal analyses were conducted for the Marin County San Francisco Bay shoreline. North of the I-580/Richmond-San Rafael Bridge, the work was performed by Northwest Hydraulic Consultants for FEMA under HSFEHQ-09-D-0368. South of the

I-580/Richmond-San Rafael Bridge, the work was performed by Michael Baker Jr., Inc., for FEMA under HSFEHQ-09-D-0368.

For the March 17, 2014 revision, BakerAECOM was contracted in 2009; contract number HSFEHQ-009-D-0368, Task Order HSFE09-09-J-0001, to perform a Physical Map Revision (PMR). This PMR incorporated community-supplied flood studies of the Mill Valley, prepared by Stetson Engineers, Inc. for the City of Mill Valley (Stetson Engineers, 2010) and the Ross Valley, prepared by Phillip Williams Associates, Ltd. under a previous contract for FEMA (Phillip Williams Associates), and was completed in August 2012.

The FIRM and FIS Report have been produced in a digital format. The flood hazard information was converted to a Geographic Information System (GIS) format that meets FEMA's DFIRM database specifications. This information is provided in a digital format so that it can be incorporated into a local GIS and be accessed more easily by the community.

Base map information for this revision was derived from multiple sources. Data was provided in digital format by Marin County Public Works Department. This information was derived from Coastal California LiDAR and Digital Imagery dated 2011. Base map information shown on the FIRM dated March 17, 2014 was derived from the sources described in Table 1, "Base Map Sources for the March 17. 2014 Revision".

Table 1 – Base Map Sources for the March 17, 2014 Revision

Data Type	**Data Provider**	**Data Date**	**Data Scale**	**Data Description**
Digital Orthophoto	NAIP	2009	1 meter GSD	Color orthoimagery was provided for the county
Topography used for delineation	Marin County	2010	45cm grid	45cm gridding of an ESRI Terrain Dataset
Political boundaries	Marin County	2000	Accuracy varies from +/ – 5 feet up to +/ – 50 feet	City boundaries
Political boundaries	FEMA	2009	Unknown	County boundaries and reservation boundaries from existing DFIRM
Transportation Features	Marin County	Unknown	Unknown	Roads and railroads were obtained from MarinMap.org
Surface Water Features	NHD	2009	1:24,000	NHD Streams downloaded from MarinMap.org
Public Land Survey System (PLSS)	FEMA	2009	1:100,000	PLSS data from existing DFIRM
Benchmarks	NGS	2010	1:24,000	Benchmarks downloaded from NGS website

On selected FIRM panels, effective May 4, 2009, planimetric base map information was provided in digital format. These files were compiled at scales of 1:4,800 with 1-foot pixel resolution and 1:12,000 with 2-foot pixel resolution. Additional information was derived from USGS Digital Line Graphs. Additional information may have been derived from other sources. Users of the May 4, 2009 FIRM should be aware that minor adjustments may have been made to specific base map features.

The coordinate system used for the production of the March 17, 2014 FIRM is California State Plane Zone III (FIPSZONE 0403), North American Datum of 1983 (NAD83) HARN, GRS1980 spheroid. Corner coordinates shown on the FIRM are in latitude and longitude referenced to the State Plane projection NAD83.

For this revision, the coordinate system used for the production of this FIRM is Universal Transverse Mercator (UTM), North American Datum of 1983 (NAD 83). Corner coordinates shown on the FIRM are in latitude and longitude referenced to the UTM projection, NAD 83. Differences in datum, spheroid, projection, or UTM zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of 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 an FIS report, 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 Marin County and the incorporated communities within its boundaries are shown in Table 2, "Initial and Final CCO Meetings."

Table 2 - Initial and Final CCO Meetings

Community	For FIS Dated	Initial CCO Date	Final CCO Date
City of Belvedere	February 1975[1]	*	February 5, 1976
Town of Corte Madera	March 1977	*	November 23, 1976
Town of Fairfax	March 1977	January 1975	February 14, 1977
City of Larkspur	September 15, 1983	July 1979 October 29, 1980	*
Marin County (Unincorporated Areas)	November 1986 May 5, 1997	December 21, 1978 May 24, 25, 27, 1983	March 25, 1981 March 20, 1996
City of Mill Valley	July 1978	July 14, 1975	January 22, 1976
City of Novato	* September 29, 1989	August 8, 1974 February 3, 1984	January 21, 1977 December 17, 1987 and November 1, 1988
Town of Ross	August 4, 1980	July 7, 1977	September 7, 1979
Town of San Anselmo	February 1977	January 1975	December 7, 1976
City of San Rafael	* January 3, 1997	July 1979 *	* *
City of Sausalito	March 1980	July 1977	November 5, 1979
Town of Tiburon	November 1976	*	April 18, 1975

[1] The City of Belvedere's FIS was unpublished
* Data not available

On October 30, 2007, the final CCO meeting for the initial Marin County countywide DFIRM and FIS was held. Attending the meeting were representatives of FEMA Region IX, MAPIX-Mainland (the study contractor), Marin County, and Cities of Larkspur and Novato.

For the March 17, 2014 revision, the initial and final CCO meetings were held on May 18, 2010 and January 17, 2013, respectively. Attending the meeting were representatives of FEMA Region IX and BakerAECOM, Marin County, and communities.

For this revision, the final CCO meetings were held on <date>. Attending the meeting were representatives of <attendees>.

2.0 AREA STUDIED

2.1 Scope of Study

This FIS covers the geographic area of Marin County, California.

Coastal flooding from the Pacific Ocean in the vicinity of Bolinas Bay has been studied in detail. In addition, this includes detailed-study reaches from Bolinas Lagoon, which supersedes previous delineations for Bolinas Lagoon at Eskoot Creek.

All or portions of the flooding sources listed in Table 3, "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 (Exhibit 2).

Table 3 - Flooding Sources Studied by Detailed Methods

Arroyo Avichi	Pacheco Creek
Arroyo Corte Madera Del Presidio Creek	Reed Creek
Arroyo Corte Madera Depression	Reed Drainage No. 1
Arroyo San Jose	Reed Drainage No. 2
Belvedere Downtown Drainage	Reed Ranch Drainage
Corte Madera Creek	Rockhill Drainage No. 1
Corte Madera Creek Overflow	Rockhill Drainage No. 2
Coyote Creek	Ryan Creek
Crest Marin Creek	San Anselmo Creek
Downtown Drainage	San Anselmo Creek Overflow
Eskoot Creek	San Rafael Creek
Fairfax Creek	Sleepy Hollow Creek
Fairfax Creek Overflow	Sorich Drainage
Hilarita Drainage	Sutton-Manor Creek
Ignacio Creek	Sycamore Park Overflow
Kittle Creek	Tennessee Creek
Lagunitas Creek	Tiburon Downtown Drainage
Miller Creek (Leveed Channel)	Tiburon Drainage
Miller Creek (Upstream Channel)	Trestle Glen Drainage
Miller Creek – Left Overbank Channel	Unnamed Tributary to Vineyard Creek
Miller Creek – Right Overbank Channel	Vineyard Creek
Novato Creek	Warner Canyon Creek
Old Mill Creek	Warner Creek
Olema Creek	Wilson Creek

Streams studied by detailed methods in the March 17, 2014 PMR include:

- Arroyo Corte Madera del Presidio Creek from San Francisco Bay to Gardner Street, approximately 2.0 miles
- Corte Madera Creek, from San Francisco Bay to San Anselmo Creek, approximately 4.2 miles

- Corte Madera Creek Overflow, from confluence with Corte Madera Creek near College Avenue to divergence from Corte Madera Creek near Lagunitas Avenue, approximately 1.2 miles
- Fairfax Creek, from San Anselmo Creek to 300 Olema Rd, approximately 1.3 miles
- Fairfax Creek Overflow, from confluence with San Anselmo Creek to divergence from Fairfax Creek near Bolinas Avenue, approximately 0.3 miles
- Old Mill Creek, from Arroyo Corte Madera del Presidio Creek to Ethel Avenue, approximately 0.3 miles
- San Anselmo Creek, Corte Madera Creek to Deer Park Creek, approximately 2.7 miles
- San Anselmo Creek Overflow, from confluence with San Anselmo Creek to divergence from San Anselmo Creek near Center Boulevard, approximately 1.1 miles
- Sycamore Park Overflow, from confluence with Arroyo Corte Madera del Presidio Creek near Valley Circle to divergence from Arroyo Corte Madera del Presidio Creek near La Goma Street, approximately 0.2 miles
- Warner Canyon Creek, from Arroyo Corte Madera del Presidio Creek to Fern Avenue, approximately 0.3 miles

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."

Table 4 - Letters of Map Change

Community	Flooding Source(s)/Project Identifier	Date Issued	Type
City of Novato	“Novato Creek Update”	August 24, 2009	LOMR

The March 17, 2014 revision of the countywide FIS supersedes two LOMRs. Case 94-09-356P was effective April 26, 1994, for the Town of San Anselmo and its determination is superseded by the new detailed analyses of San Anselmo Creek and San Anselmo Creek Overflow. Case 10-09-0374P was issued to incorporate new topographic data effective March 31, 2010, for the City of Mill Valley, and is superseded by the new detailed analyses of Arroyo Corte Madera del Presidio Creek and Warner Canyon Creek.

This <date> revision of the countywide FIS supersedes one LOMR. Case 09-09-2065P was effective October 8, 2009, for the City of Novato and its determination is superseded by the new detailed coastal analyses for the Marin County San Francisco Bay shoreline.

LOMR 09-09-2365P is not incorporated in this Physical Map Revision since it is outside the panels affected by this PMR. This unincorporated LOMR remains effective.

The areas studied by detailed methods were selected with priority given to all known flood hazard areas and areas of projected development and proposed construction.

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 Marin County.

2.2 Community Description

Marin County encompasses the entire peninsula that forms the northwestern boundary of San Francisco and San Pablo Bays, extending north to the Petaluma River estuary on the east and to Bodega Bay on the west. The county covers an area of approximately 521 square miles in central California along the west coast. The county includes 11 incorporated cities and numerous unincorporated communities. The 2010 population of Marin County was 252,409. There is a combination of State, county, city, and private road networks consisting of over 650 miles. The San Andreas geologic fault runs approximately north and south in the western part of the county. Approximately two-thirds of the county border is adjacent to water. Marin County is bounded by Sonoma County to the north, Contra Costa County to the east, and San Francisco City and County to the south.

Incorporated cities in Marin County are mostly along the eastern edge of the county. Most of the flatland along the creeks studied has been developed to moderate-density suburban areas with very high land values. Most of the western areas of the county are incorporated into the Golden Gate National Recreation Area or state parks. Little new development can be accommodated in many of the areas studied. Drainage basin areas for the studied streams are small and this, combined with the steep terrain, results in rapidly developing streamflows of short duration.

Topographically, Marin County can be described as hilly to mountainous. Typically, the county consists of numerous relatively flat, narrow valleys that lie between steep to rolling ridges varying in height from a few hundred feet to more than 1,000 feet. The mountainous character of the county significantly affects precipitation distribution. The climate of Marin County is characterized by warm, dry summers and mild, wet winters. The hottest month is July, with a mean daily maximum temperature of 83 degrees Fahrenheit (°F). The coldest month is January, with a mean daily minimum temperature of 38°F. Snowfall is rare and has no effect on flood runoff. Precipitation is concentrated during October through April, when 95 percent of the seasonal precipitation normally occurs. Normal annual precipitation ranges from 30 inches in the north to approximately 60 inches along the higher ridges of the county.

Soils are generally shallow, except in the valley areas, and vegetation ranges from mostly non-native plants in the suburban areas to large second- and third-growth timber and annual grasses on the steeper slopes.

The unincorporated communities of Bolinas and Stinson Beach are approximately 15 miles northwest of San Francisco along Bolinas Bay. Bolinas is located on the western headland of the Bolinas Lagoon, while Stinson Beach is located on the sand spit that separates the lagoon from the ocean. The lagoon inlet separates Bolinas from Stinson Beach. Both communities are residential resort areas, and virtually all beachfront properties have been developed. No new developments are known at this time.

2.3 Principal Flood Problems

The principal watercourses in Marin County are Coyote Creek, Reed Creek, Sutton-Manor Creek, Eskoot Creek, Novato Creek, Miller Creek, Lagunitas Creek, Olema Creek, Rush Creek, and their tributaries.

Six non-natural reservoirs in the county are adjacent to the San Andreas fault. An earthquake could rupture the dams and cause flash flooding in populated areas. These dams offer no flood protection because they were built primarily for water supply.

The floods in Marin County are normally of short duration, lasting only 3 or 4 days. Floods may develop within 24 hours after the beginning of a flood-producing storm and will normally recede within 1 day after the end of the storm. Tributaries rise rapidly, so that flooding begins a few hours after the occurrence of heavy rainfall. Sheetflow flooding is caused by inadequate channel capacity and poor drainage in areas close to streams.

Flood peaks for the streams in Marin County generally occur between December and March, although records show that they have occurred as early as November and as late as April.

Rainfall over much of the basins studied is heavy, and rainy season flooding is frequent. Since 1950, major floods have occurred in 1952, 1955, 1958, 1967, 1969, 1970, 1973, and 1975, with the storm of December 1955 generally considered to be the largest of this period. However, while most streams studied have short or nonexistent gage records, it is unlikely that any storm in this period produced peak stream discharges greater than a 20- to 25-year event on the basins studied.

The flooding conditions on the minor streams of Marin County are similar to those found in the major basins.

Coastal flooding in Marin County is typically associated with the simultaneous occurrence of very high tides, large waves, and storm swells during the winter. As a result, oceanfront development has not been compatible with the natural instability of the shoreline and the intense winter weather conditions.

Tsunami (sea waves generated from oceanic earthquakes, submarine landslides, and volcanic eruptions) create some of the most destructive natural water waves. As tsunami waves approach shallow coastal waters, wave refraction, shoaling, and bay resonance amplify the wave heights.

Storm centers from the southwest produce the type of storm pattern most commonly responsible for the majority of the serious coastal flooding. The strong winds and high tides that create storm surges are also accompanied by heavy rains. In some instances, high tides back up riverflows, which causes flooding at the river mouths.

The most severe storm to hit the Marin County coastline occurred in 1978 and 1983 when high-water levels were accompanied by very large storm waves.

In January 1978, a series of storms emanated from a more southerly direction than those that normally occur; consequently, some of the better-protected beaches were damaged.

Jetties and breakwater barriers were overtopped and in some cases undermined. Direct wave damage occurred to many beachfront homes, especially in the more populated beachfront areas in Stinson Beach. Accelerated erosion coupled with saturated ground conditions and rain weakened the foundations of homes in Bolinas located on the top of beach bluffs. Seawalls and temporary barriers failed to protect beachfront properties from the ravages of the 1978 storms.

The winter of 1983 brought an extremely unusual series of high tides, storm surges, and storm waves along the California coast (Ott Water Engineers, Inc., 1984).

All floods of any consequence in the Town of Corte Madera have occurred in the low areas that have been reclaimed from the bay's marsh and tidal lands. Generally speaking, these reclaimed areas encompass everything in and east of the Madera Gardens and the lands north of Paradise Drive. These areas constitute one-half of the present town area.

Flooding can result from either of two phenomena. The first is from storm runoff originating within the Town of Corte Madera and flooding low lands due to inadequate drainage channels and pipes necessary to transport this water into San Francisco Bay (sheet flooding). The second cause is from high water in the bay that in turn pushes salt water up into the stream channels and inundates all lands below the tide level that are not leveed. The elevation of the water surface in the bay is dependent upon the tide, local runoff, and wind and wave effects.

The extent of flooding has been further complicated by the fact that some of the originally reclaimed tidal lands were not filled high enough. The clay materials in the bay mud are so unstable that land subsidence takes place over periods of 30 years to 50 years. Thus, certain areas in the Town of Corte Madera have subsided to elevations that now cannot be drained with the existing storm drainage system.

Another flood complication is the gradual filling of the tidal lands that served originally as natural ponding areas. The storm waters that would have drained to these areas must now proceed down the channels and into the bay, or to other low lands where ponding can occur.

There is modest documentation as to the extent or depth of prior flooding in the Town of Fairfax. Information supplied by local residents indicates that flooding has occurred in the lower segments of Fairfax Creek, Deer Park Creek, Bothin Creek, and Wood Lane Drainage during major storm events. Estimates made by the USACE indicate that major damage occurred in Fairfax during the 1942 and 1955 floods (USACE, 1961). For the March 2014, PMR, identification of parcels affected by December 2005 flood affected derived from the undated exhibits prepared for Marin County, along with high water observations from that storm event provided by Stetson Engineers, Inc.

The principal causes of flooding in the City of Larkspur are the local watercourses overtopping their banks during extreme rainfall, and the inability of the topography and drainage system of the city to handle torrential rains which have occurred at various points in time. Significant flood damage from these sources occurred in December 1955, April 1958, January 1973, and January 1982. In recent years, as development has intensified in the City of Larkspur, the potential for flooding has increased. By virtue of the level of development and rainfall intensity, the flood of January 1982 was the most damaging within Marin County in general and the City of Larkspur in particular.

Following are descriptions of significant historical flood events which have occurred in the City of Larkspur. The severity of the floods, and the relative development of the area at the time, significantly influenced the extent of damage. In the more recent flood years, particularly 1982, the instance of mudslides has increased dramatically, including the destruction of a large number of homes located on hillside sites. This increase in mudslide occurrences appears to be a function of both site selection and the level of development.

The flood of late December 1955 was one of the most devastating throughout the State of California. Marin County sustained extensive damage during this event. The headline in the Thursday, December 22, 1955, San Rafael Independent Journal read, "Hundreds of Marin families leave homes submerged by flood." The southern portion of the county (near the Town of Fairfax and the City of Mill Valley) appears to have been less severely damaged than communities in the central section of the county, including the City of Larkspur. The San Rafael Independent Journal of Thursday, December 22, contained the following account:

> Swollen creeks cascading over banks, heavy continuing rain, innumerable slides, and clogged drainage basins, combined to create one of the worst traffic snarls in Marin history . . . (San Rafael Independent Journal, 1955).

In the City of Larkspur, one of the most seriously damaged areas was the Heather Gardens subdivision. Many families had to be evacuated by rowboat. As described in the December 22, 1955, edition of the San Rafael Independent Journal, flooding of streets was also widespread.

> Also hard hit by flooding and slides, closed streets include Heather Gardens, College Park, Marina Vista, West Baltimore, Murray Avenue, and Ridgeview Road (San Rafael Independent Journal, December 22, 1955).

The damage throughout Marin County was severe enough for the area to be designated by the Federal Government as a disaster area. The Wednesday, December 28, 1955, issue of the San Rafael Independent Journal contained the following headline: "U.S. offers funds to repair damage here." A subsequent article indicated "Federal funds are available for rehabilitation of flood damage, public property, and for small businessmen and homeowners eligible for them" (San Rafael Independent Journal, December 28, 1955).

The torrential rains of early April 1958 culminated in flood conditions for numerous areas in northern California. The City of Larkspur was no exception. The San Rafael Independent Journal of Wednesday, April 2, 1958, carried the following account:

> At the storm's peak, shoppers were marooned at Bon Air shopping center when water rose to curb height, flooding the entire parking area (San Rafael Independent Journal, April 2, 1958).

The flooding noted above resulted from exceptional precipitation in the Larkspur area. As noted in the San Rafael Independent Journal of April 3, 1958, "San Rafael increased the season's rainfall total to 58.7 inches. Such a total has never been recorded here by April 3 in the past" (San Rafael Independent Journal, April 3, 1958).

Flood conditions in the City of Larkspur area in mid-January 1973 were brought about by two storms that occurred within a 4-day period. The headline of the Independent Journal of Friday, January 12, 1973, proclaimed "A ruinous storm slams into area." Four days later, a second headline stated "Sagging Marin hit by savage storm." The Independent Journal of January 16, 1973, carried the following description:

> Central Marin County was widely flooded, with Fourth Street in San Rafael the only major street in the city where traffic was moving at times today. Corte Madera and Larkspur also reported heavy flooding (Independent Journal, January 16, 1973).

By Wednesday, January 17, 1973, an initial assessment of storm damage had been completed. The Independent Journal reported the following:

> Two violent storms, which have brought trouble and despair to Marin County, were blamed yesterday by county officials for causing nearly $2 million damage countywide; an estimate likely to climb before the week is out . . . Larkspur damage was put at $125,000, as was Sausalito's . . . (Independent Journal, January 17, 1973).

The storm which hit California on January 4, 1982, was the worst in the state since 1955. The Larkspur area, as was the case with many areas in northern California, experienced extreme damage as a result of the storm. One of the first accounts of the damage appeared in the Tuesday, January 5, 1982, issue of the Independent Journal:

> Four homes, two in Madrone Canyon and two in the Murray Park area, toppled from their foundations and were destroyed; hundreds of homes were flooded (Independent Journal, January 4, 1982).

The 1982 flood had a different damage profile than previous floods. The greatest loss of property—and in this case loss of life—was due to mudslides. The headline in the January 7, 1982, edition of the Independent Journal captured the feeling in the local area: "Terrifying moments in Larkspur landslide." The article described damage in another section of Madrone Canyon:

> Deborah McCray sat on her neighbor Jeanne Johnson's deck above a gash in the ground where her own home used to be in the Madrone Canyon area of Larkspur.
>
> She and Jeanne, who lives at 17 Jones Way, were in Ms. McCray's house at 11 Jones Way when a wall of mud and water roared down a steep gully Monday ripping it to pieces. James McCray and Chuck Johnson, their husbands, thought they saw their wives die. The avalanche hit while they were outside fixing drains to stop the water from flowing into the McCray home.
>
> 'We were trying to move the furniture from the first floor to the second floor,' said Ms. Johnson. 'We had just made one run,'

> Ms. McCray added. 'All of a sudden, I heard this incredible roar—wood cracking and breaking. Jeanne and I, without saying a word, just threw ourselves out the door' (Independent Journal, January 7, 1982).

This occurrence was all too frequent in Marin County. Twenty-one homes were destroyed in neighboring the City of San Rafael. One woman lost her life in a slide there.

By Saturday, January 9, 1982, a somewhat accurate assessment had been made of the damages in the City of Larkspur and Marin County. The Independent Journal reported the following:

> A 32-hour assault by 12 inches of rain unleashed 'rivers of destruction' Monday in Marin County. Four people were killed. More than 100 homes were either totally destroyed or substantially damaged. Another 2,000 were swamped by flood waters that soaked into the furniture and deposited a layer of silt on the floors. The storm sent more than 2,000 Marin residents rushing to evacuation centers set up across the county . . .
>
> By Wednesday morning, total damage in Marin County was estimated at over $100 million. In Sonoma County, it was over $16 million. To the south in Ben Lomond in Santa Cruz County, 14 deaths were reported and the total was expected to rise.
>
> The reports moved President Ronald Reagan to authorize Federal aid for Marin and five other bay area counties that had already been declared disaster areas by Governor Edmond Brown, Jr. (Independent Journal, January 9, 1982).

Damage estimates for the storm of January 4, 1982, continued to accumulate upward for a period of months after the storm. The accounts given indicate the severe and immediate implications of flood damage in the Larkspur area as a result of that event.

Existing drainage is inadequate and the flood problems are accentuated by encroachment of residential developments upon the channels. Channel capacities have been reduced to the extent that flooding occurs in the low areas whenever there is an intense storm over the Arroyo Corte Madera del Presidio basin. In areas where the general ground was lower than the stream channel, development was made possible by using random fill to reclaim the land. This reclamation was accomplished at different times under varying governing criteria. As a result, low pockets of land have developed along the channel. During overbank flow, ponds in these areas make flood damage a function of duration as well as peak. Near the lower portion of Arroyo Corte Madera del Presidio, a residential development has been built on bay fill along the north side of the stream channel, immediately upstream from Camino Alto and south of

Sycamore Avenue. This fill formed a sump area where it meets the natural valley slopes. Flooding occurs in the sump area nearly every year. Beginning in the vicinity of Willow Street and extending downstream, flooding occurs because the channel is above the surrounding ground. Overbank flows do not return to the channel until they reach Camino Alto because of the natural topography (USACE, 1969; USACE, 1973). Adding to the problem is the inadequacy of the existing drainage system in this area.

The peak flood discharge of December 22, 1955, the most severe storm of recent history, was computed to be 2,260 cubic feet per second (cfs) at Camino Alto bridge over the Arroyo Corte Madera del Presidio. During this flood, basin precipitation was estimated to be 2.5 inches during the 6-hour period of most intense rainfall. Areas adjacent to Richardson Bay are subject to tidal flooding. The elevation of the 1-percent annual chance tide in Richardson Bay would be 6 feet.

The Novato Creek basin has a long history of flooding. Prior to 1955, much of the land was agricultural; urbanization has changed the hydrologic response of the watershed markedly over the past few years. Runoff during periods of excessive rainfall produces peak flows in excess of channel capacities. Many times, conduits get choked with trees, and culverts become clogged. Sheetflow from the upland areas reaches downstream and causes serious ponding. The problem becomes more serious when overbank flows commingle with local drainage inlets and ditches. Occasionally, high flows will occur several times during the same year, as they did in 1973.

The major channels are under the jurisdiction of the Marin County Flood Control and Water Conservation District. The County's Novato Creek Flood Control Project, which is under construction (1987-1989) (Camp, Dresser and McKee, Inc., 1983), consists of flood control improvements to Novato and Warner Creeks and Arroyo Avichi (see Section 2.4), but do not include improvements to local drainage facilities.

Prior to the improvements currently being made, Novato Creek, Warner Creek, and Arroyo Avichi were incapable of passing even relatively frequent floods without some overbank flow. With the completion of the flood control project, Novato Creek, between its confluence with Warner Creek and the upstream corporate limits, will experience overbank flows when the flow exceeds 3,300 cfs. From its confluence with Warner Creek to its confluence with Arroyo Avichi some overbank flow will occur when the flow exceeds approximately 4,690 cfs. Novato Creek downstream of Arroyo Avichi to the Northwestern Pacific Railroad bridge will have overbank flow when the flow exceeds approximately 5,140 cfs. From the railroad bridge downstream to San Pablo Bay, the channel capacity is approximately 2,500 cfs and overbank flow will occur when the discharge exceeds that amount.

Warner Creek, from its confluence with Novato Creek upstream to its confluence with Wilson Creek, has a channel capacity of approximately 1,800 cfs and will experience overbank flow when the flow exceeds that amount. From its confluence with Wilson Creek upstream to its confluence with Vineyard Creek, Warner Creek will have overbank flow when flows exceed approximately 830 cfs. Along Vineyard Creek some overbank flow will occur upstream of Center Road when flow exceeds approximately 700 cfs and upstream of Trumbull Avenue when the flow exceeds approximately 850 cfs. Wilson Creek has similar problems upstream of Center Road and Shields Lane with overbank flow occurring when channel flows exceed approximately 450 cfs and 800 cfs, respectively.

The potential flood problems associated with Arroyo Avichi result mainly from inadequate capacities of the 10- by 3-foot box culvert under South Novato Boulevard and the triple, 700-foot long, 42-inch diameter concrete pipes leading directly into the culvert (USACE, 1971).

Heavy rain associated with thunderstorms is the primary cause of flooding in the Town of Ross. Prior to establishment of the USGS stream-gaging station on Corte Madera Creek at the Town of Ross in February 1951, major flooding was reported in 1914, 1925, 1937, and 1942 (USACE, 1961). Since the station has been in operation, major floodflows have been recorded in 1951, 1955, 1958, 1967, 1969, and 1970. The maximum flood since the station was installed occurred in 1955 and caused major flooding in the Town of Ross adjacent to Corte Madera Creek. This flood has an estimated probability of .04, or a recurrence interval of 25 years. The most recent flood occurred in 1970 and has a recurrence interval of approximately 6 years.

Major flooding in the Town of Ross is directly attributable to overflows from Corte Madera Creek or high water-surface elevations in the creek proper. Initial flooding is in the form of sheet flow caused by Corte Madera Creek overbank flows in the Town of San Anselmo immediately upstream from the Town of Ross (U.S. Department of Housing and Urban Development, 1977). This shallow flooding enters the Town of Ross across Bolinas Avenue and continues south along the west side of Sir Francis Drake Boulevard to approximately 400 feet upstream of the confluence of Corte Madera Creek and Ross Creek.

Along the right bank of Corte Madera Creek from Ross Creek to Lagunitas Road and along the left bank from Sir Francis Drake Boulevard to the vicinity of Berry Lane, flooding is caused by inadequate channel capacity and the constriction at Lagunitas Road. Downstream from Lagunitas Road, flooding along the right bank of Corte Madera Creek is in the form of sheet flow which is separated from the main channel by the abandoned railroad bed. This sheet flow would completely inundate Murphy Creek and the surrounding area during the 1-percent annual chance flood.

Along the left bank, floodwater elevations in Corte Madera Creek downstream from Lagunitas Road dominate the flooding along the lower portion of Kittle Creek to the vicinity of Berry Lane. Below Berry Lane, flooding is in the form of sheet flow, some of which empties back into the Corte Madera channel.

Downstream from Walters Road, Kittle Creek passes under several buildings of the Marin Art and Garden Center through culverts where floodwaters leave the channel and flow in sheet-flow form along both banks. Upstream from Walters Road, flows overtop the southern portion of Laurel Grove Avenue to the centerline. Flows are contained by the eastern bank of the Kittle Creek channel above Walters Road.

The flood of record occurred in 1982, with a frequency of 150 years, and it was during this period that major flooding occurred in the downtown area of the Town of San Anselmo along San Anselmo Avenue. Channel constrictions adjoining San Anselmo Avenue were the primary cause of the overbank flows. Trash buildup at these constrictions (bridges and enclosed channel segments) also added to the flood problem. Similar flooding, to a lesser degree, occurred in 1955, 1969, and 2005.

Flooding will occur along San Anselmo Creek during the base flood between Calumet Avenue and Sycamore Avenue due to inadequate channel capacity and backwater caused by the development of commercial structures adjacent to and over the channel in the business district along San Anselmo Avenue. Floodwaters forced from the channel in this latter area will flow through the business and residential area west of San Anselmo Avenue and into the Town of Fairfax in the form of sheetflow. San Anselmo Creek from Sir Francis Drake Boulevard to the Town of San Anselmo corporate limits will contain the flows remaining in the channel after the overflow in the downtown business district.

Sleepy Hollow Creek will contain the 1-percent annual chance flow considered in this study from the western corporate limits to a point approximately 350 feet upstream from Arroyo Avenue. Base flood inundation between Carlson Avenue and Arroyo Avenue is a result of backwater from the hydraulic structure at Arroyo Avenue. The reach from Arroyo Avenue to Sir Francis Drake Boulevard is characterized by smaller channel conveyances. Backwater effects from the elevated roadway, constrictive hydraulic opening at Sir Francis Drake Boulevard, and these channel characteristics will cause extensive flooding throughout this reach during the 1-percent annual chance flood. During lesser flood events, ponding occurs when the drainage system cannot discharge to the creek during high stages. Floodwaters topping Sir Francis Drake Boulevard will return to Sleepy Hollow Creek downstream of Sir Francis Drake Boulevard and also flow to San Anselmo Creek in the form of shallow sheetflow. Some of these floodwaters will inundate a depressed area along Sir Francis Drake Boulevard near Ash Avenue as sheetflow. The reach from Sir Francis Drake Boulevard to the confluence with San Anselmo Creek will contain that portion of the 1-percent annual chance flow remaining in Sleepy Hollow Creek after overflow to San Anselmo Creek.

Minor flooding in the form of shallow sheetflow will occur downstream from Santa Cruz Avenue in the Sorich Drainage and in the adjacent Red Hill Drainage between Sunnyhills Drive and Arbor Road during the base (1-percent annual chance) discharge considered in this study. Flooding, however, will be confined to streets, depressions, and small overland flow areas. Confinement of the natural channel to culverts is the primary cause of flooding.

Natural channels within Greenfield Drainage and Laurel Drainage (including the drainages along Scenic Avenue and south of Center Boulevard) have been confined to conduits that cannot contain the larger discharges considered in this study. Resultant shallow sheetflow will inundate areas within these drainages during the base (1-percent annual chance) flood.

The City of San Rafael is subject to both freshwater and tidal flooding. The two major tidal flooding areas are along the lower portions of Gallinas and San Rafael Creeks.

The principal causes of freshwater flooding in the City of San Rafael are the local watercourses overtopping their banks during extreme rainfall, coupled with the inability of the topography and drainage system of the city to handle various torrential rains which have occurred.

Tidal flooding has occurred in the waterfront area near Harbor Drive and Gate 5 Road. No data have been recorded for floods in the City of Sausalito; however, floods have been recorded in the San Francisco Bay area in 1955, 1958, 1969, and 1970.

In recent years, flooding in the Town of Tiburon has been reported during the general flood periods of 1955, 1958, 1967, 1970, and 1973. Frequent flooding has occurred along Tiburon Boulevard, from Mar West Street to Main Street, and to the south past Juanita Lane throughout the business section. Areas to the north of Tiburon Boulevard have also been inundated. Minor flooding has occurred in the Rock Hill drainage, particularly south of Tiburon Boulevard in the vicinity of Palmer Avenue; severe flooding has occurred in the Miraflores drainage.

Flooding is generally the result of intense, short period rainfall within a general storm period (Hudis, M., 1971). Flooding can occur in the Town of Tiburon due to the estimated 1- and 0.2-percent annual chance discharges. Within the Downtown and Tiburon drainages, flooding in the form of sheet flow can take place when reverse flow occurs due to the restrictive flowageway to Belvedere Lagoon. This reverse flow along Tiburon Boulevard is joined by overflow from the pond north of Tiburon Boulevard when the estimated discharges exceed the capacity of the natural pond and pump/canal facility. The topography of the area is such that the floodflows will eventually flow to Belvedere Lagoon. To the north of the pond, minor flooding can occur from the 1-percent annual chance discharge; but a larger area will be inundated during the 0.2-percent annual chance occurrence when conduit facilities under the Tiburon Tennis Club are exceeded.

The lower reaches of the Reed drainages can be expected to flood during the more extreme flood events, particularly the area of Reed School, when the conduit capacity is exceeded during the 1- and 0.2-percent annual chance occurrences. During the 0.2-percent annual chance occurrence, excess floodwaters from both Reed drainages combine to overflow Tiburon Boulevard en route to Belvedere Lagoon.

Flooding within the Rock Hill drainages can occur north of Tiburon Boulevard when culvert capacities are exceeded; and overflows, directed by the topography, proceed to Tiburon Boulevard as sheet flow and eventually to Richardson Bay. South of Tiburon Boulevard, sheet flow can occur along the Rock Hill No. 1 drainage near Palmer Avenue, with the resulting flows ponding behind the old railroad embankment along the shore of Richardson Bay. Additional ponding can occur when the estimated 0.2-percent annual chance flood flows from both Rock Hill drainage ponds behind the embankment and inundate areas of the Belvedere Tennis Club. Flooding, in the form of sheet flow, may occur through the Del Mar School during the estimated 1- and 0.2-percent annual chance floods.

Tidal flooding may occur at the extreme lower portion of the Trestle Glen drainage during the estimated 1- and 0.2-percent annual chance tides on Richardson Bay. To the west, in the area of Greenwood Beach Road and Tiburon Boulevard sheet flow can occur. In addition, sheet flow can occur in the area of Trestle Glen Boulevard and Mercury Avenue when street flows combine with Trestle Glen drainage overflows at Mercury Avenue. A minor area of flooding can also occur during the estimated 0.2-percent annual chance discharge in the Reed Ranch drainage.

One area of concern when considering flooding in the City of Belvedere is the drainage from the southwest-facing slopes of the Tiburon Peninsula. This flow is via the Hilarita, Reed #1, Reed #2, and Belvedere Downtown Drainage. Floodwaters from these drainages flow through the City of Belvedere in conduits and overland to Belvedere Lagoon and Richardson Bay (Hilarita Drainage). The overland flow results from drainage facilities that will accommodate only more frequent, minor floods. Excess floodwater from the Belvedere Downtown Drainage may at times flow through the downtown business areas of the Cities of Tiburon and Belvedere, and eventually to Belvedere Lagoon in the vicinity of Cove Road.

The second area of concern in the City of Belvedere is the drainage from the north-facing slopes of Belvedere Island where the larger, less frequent floods will exceed the capacity of existing drainage facilities and excess water will flow overland to Belvedere Lagoon.

The third area of concern in the City of Belvedere is created when the tide in San Francisco Bay overtops San Rafael Avenue during the most extreme event considered, the 0.2-percent annual chance tide, and tidal waters flow to Belvedere Lagoon.

The possible effects of landslides, mudflows, land subsidence, earthquakes, or tsunamis were not studied for the City of Belvedere.

2.4 Flood Protection Measures

No projects are being maintained or operated by the USACE in Marin County. From time to time, under the authority of Public Law 99, 84th Congress, or Public Law 875, 81st Congress, emergency channel restoration, and levee repairs have been carried out.

Flood-control projects (concrete channels) have been built in Marin County by the USACE; one is on Coyote Creek, and one is on Corte Madera Creek. The projects have no effect on the 1-percent annual chance (100-year) and 0.2-percent annual chance (500-year) floods and do not affect the floodplain or discharges.

Local interests have constructed approximately 75 miles of levees in the county. These levees are concentrated in the low-lying areas around Richardson Bay and the Cities of San Rafael and Novato.

A Marin County ordinance controlling tidal areas states that the first floor of a structure must be at an elevation of at least 9.69 feet (assumed to be NAVD 88).

Over one-half of the Stinson Beach peninsula has been riprapped for shore protection, although the southern portion of the beach is unprotected. It is expected that if this shore protection is maintained, it will withstand the 1-percent annual chance flood (Ott Water Engineers, Inc., 1984).

In order to control the substantial amount of storm water runoff from the steep slopes of Corte Madera Ridge and the impervious surfaces in the developed areas of town, and to prevent flooding of the lowlands, developers in the past found it necessary to build a system of lagoons and drainage canals. Most of the storm water runoff is discharged into Corte Madera Creek but San Clemente Creek, east of the Redwood Highway, drains a large portion of the eastern half of the town to San Francisco Bay.

Foreseeing the need for additional drainage works to facilitate new development, the town adopted a comprehensive drainage plan in April 1956. The plan designates certain areas for the “high level” fill method and other areas for the “low level” fill method. The developer has the choice of alternatives on certain other properties. The “high level” method involves filling low areas to elevations that are high enough to drain properly against the highest probable tides. The “low level” method involves protection of the area to be developed by use of levees, so that fills are placed at a much lower elevation than with the high level method. The low level method also calls for a holding pond or a lagoon so as to hold storm water during high tide periods until the water can be discharged into the bay through use of pumps or culverts equipped with tide gates.

A comprehensive drainage plan has been in effect in the Town of Corte Madera. The drainage problems have become much more severe, and areas built in conformance with the drainage plan recommendations have also experienced flood damage. The rapid increase in population and the accompanying development of housing facilities during this period have served to accentuate the damage problems.

All drainage ways and channels that carry runoff in the Town of Corte Madera have been partially or fully modified from their natural state. These modifications have been in the form of straightened channels or pipelines. Each channel originates at the ridge on the southern boundary of the Town of Corte Madera and traverses northerly so as to empty into Corte Madera Creek, San Clemente Creek, or San Francisco Bay.

The channels are dry in the summer, except for small quantities of irrigation return waters. When the winter rains begin, the channels again carry water during and after each storm. There are no stream gaging stations for the channels in the Town of Corte Madera.

There are two manmade lagoons in the Madera Gardens area, designated as Lagoon No. 1 and Lagoon No. 2. These lagoons were constructed as part of the Madera Gardens subdivision for the purpose of collecting and holding storm runoff during high tide periods and then discharging the collected water into Corte Madera Creek during periods of low tide.

The USACE has constructed channel improvements from the mouth of Corte Madera Creek upstream to the Town of Ross, a distance of about 3.5 miles. These channel improvements will alleviate the periodic inundation that has occurred in the lower floodplain where public, commercial, and residential developments have taken place.

Two major drop structures exist on San Anselmo Creek at Canyon Road and Pastori Avenue, their primary purpose being the reduction of erosive stream velocities. There is also a small dam on Fairfax Creek along Olema Drive (upstream from Westbrae Avenue) which acts as a drop structure. Fairfax Creek is diverted to San Anselmo Creek in a 10-foot by 6-foot conduit at Bolinas Avenue. None of these structures, however, provide significant protection from flooding in these areas.

The USACE performed channel improvements from the mouth of Corte Madera Creek upstream to the Town of Ross, a distance of about 3.5 miles. These improvements, in the form of channel straightening, lining, and dredging, have alleviated the periodic inundation that has occurred in the lower floodplain.

Storm runoff from the slopes of Corte Madera Ridge, combined with the urbanization effects of the city, has necessitated drainage improvement of Larkspur Creek. The channel improvement has been in the form of a culvert extending from Monte Vista Avenue to about Meadowood Drive.

Some additional flood control benefits have been derived from the upstream operation of the water supply reservoir on Phoenix Lake. However, these benefits are negligible for floods of 1-percent annual chance magnitude or larger. Other improvements have consisted of bridge, levee construction, and bank protection from tidal flooding. These efforts are generally inadequate in protecting the city from 1-percent annual chance tidal flooding.

Local interests in the City of Novato have performed some channel clearing, widening, and bank protection measures as part of the community maintenance program. The lower reach of Novato Creek is afforded some protection by earth levees. The levees begin downstream from Diablo Avenue approximately 76,500 feet above San Pablo Bay and extend to San Pablo Bay. The channel invert, as well as adjacent lands, are approximately at sea level. Streamflow is contained between levees and is equal to less than the 10-year event.

Additional flood control storage was provided in Stafford Lake with modifications to the dam's spillway. The spillway modifications, used to delay the passage of floodflows to downstream areas, were proposed by the Marin County Flood Control and Water Conservation District and were funded through a measure passed by the electorate following the flood of January 1982. The spillway was raised to an elevation of 201.69 feet NAVD through the use of a 3-foot-deep, 10-foot-wide notch; at the same time, the earth embankment of the dam was raised to an elevation of 216.69 feet NGVD to prevent overtopping of the dam during the probable maximum flood.

The Flood Control and Water Conservation District is also constructing (1987-1989) a flood control project which will provide approximately 2-percent annual chance protection for Warner Creek and Novato Creek (Camp, Dresser and McKee, Inc., 1983). Immediately downstream of the Northwestern Pacific Railroad bridge, an overflow weir will be constructed to divert floodwaters into a new detention pond at Deer Island. Channel improvements on Novato Creek will start at the Northwestern Pacific Railroad bridge approximately 2,000 feet downstream of U.S. Highway 101 and will continue upstream to the Grant Avenue Bridge. The channel capacity will be increased from the downstream end of the project to just upstream of the Warner Creek confluence by channel excavation and improvements to the Northwestern Pacific Railroad and Redwood Boulevard Bridges. From Warner Creek to Diablo Avenue, channel improvements to Novato Creek will consist of minor channel excavation and earthen berms constructed along portions of the creek where the existing bank elevations are below the level of 2-percent annual chance floodflows. From Diablo Avenue to Grant Avenue, improvements will consist of low (0 to 3 feet high) concrete walls constructed along portions of Novato Creek where the existing bank elevations are below the level of 2-percent annual chance flood flows.

Improvements to Warner Creek start at its confluence with Novato Creek and continue upstream to McClay Road. The channel capacity will be increased by channel excavation, concrete lined channels, concrete walls and/or earthen berms.

Additional box culverts will be constructed under South Novato Boulevard, Diablo Avenue, and McClay Road.

Arroyo Avichi has been improved with the addition of a diversion channel and a detention pond that will provide temporary storage of flows in excess of the capacity of the three existing concrete pipes.

Corte Madera Creek channel improvements, proposed by the USACE in September 1961 (USACE, 1961) and modified in July 1966 (USACE, 1966), have been completed from the southern corporate limits to a point approximately 600 feet downstream from Lagunitas Road in the Town of Ross. The channel improvement is a concrete-lined channel designed to convey the Standard Project Flood.

Phoenix Lake, outside the Town of Ross on Ross Creek, is a water conservation feature owned and operated by the Marin Municipal Water District. Flood control benefits from Phoenix Lake are incidental to operations for water-conservation storage. Flood control of the 1- and 0.2-percent annual chance floods provided by Phoenix Lake is negligible (USACE, 1961).

The weir at Saunders Avenue on San Anselmo Creek and the concrete dam in the upper reaches of the Laurel Drainage near Redwood Road are the only known flood protection measures in the Town of San Anselmo. The dam is effective only during smaller flood events and would have a minimal effects on the base flood considered in this study. The weir does not have any effect on flood flows.

No Federal flood control facilities exist on the streams within the City of San Rafael.

There are no structural flood protection measures for eliminating tidal flooding. In the past, flooding has occurred west of Bridgeway and north of Coloma Street. This pondage was the result of the lack of adequate drainage facilities for conveying floodwaters from Coloma Drainage to Richardson Bay. A storm drain has been constructed, and most of this flooding will be eliminated.

A small, natural retarding pond, together with an automatic pump and canal located within the Town of Tiburon, serve to control flooding from the Tiburon Downtown Drainage during minor, more frequent storm events. Larger flood flows, however, overflow the pond and inundate a part of the City of Belvedere before flowing into Belvedere Lagoon. A hydraulically operated tidal gate at San Rafael Avenue is used to lower the water surface in Belvedere Lagoon to -0.4 foot (above NAVD) during the wet season, or to raise it to +1.6 feet (above NAVD) during the dry season. Lowering of the water surface for increased flood-control storage is restricted during periods of high tide. Generally, the period of highest tides occur during the winter storm season. Calculations of flood levels in Belvedere Lagoon are based on a lagoon elevation of -0.4 foot (NAVD) prior to a maximum tide or storm event.

3.0 ENGINEERING METHODS

For the flooding sources studied in detail in the county, 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 100-year flood (1-percent chance of annual exceedence) 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 county 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 the flooding sources studied in detail affecting the county.

Revised Analysis

For this revision of the countywide FIS, hydrologic analyses for the Mill Valley and Ross Valley restudy determined the 10-, 4-, 2-, 1-, and 0.2-percent annual chance peak discharges for the Arroyo Corte Madera del Presidio Creek, Corte Madera Creek, Fairfax Creek, Old Mill Creek, San Anselmo Creek, and Warner Canyon Creek using stream gage analyses based on Bulletin 17 B methodology (U.S. Water Resources Council, 1981) and supplemented with the USACE HEC-HMS Version 3.3 (USACE, 2008) computations for the distribution of flows within each watershed. The balance of peak discharges for the Corte Madera Creek Overflow, Fairfax Creek Overflow, San Anselmo Creek Overflow, Sycamore Park Overflow, and their divergent flooding sources were determined using the split flow optimization routine in the HEC-RAS Version 4.1.0 hydraulic model (USACE, 2008).

First Time Countywide Analysis

Information on the methods used to determine peak discharge-frequency relationships for the streams restudied as part of the initial countywide FIS is shown below.

A HEC-1 model (USACE, 1981) developed for Miller Creek as described in a previously published FIS for the unincorporated areas of Marin County (FEMA, 1986), was used as the basis for the hydrology. The revised portion of Miller Creek is a perched channel. During the 1-percent annual chance flood event, flow leaves the channel into the adjacent overbanks and forms two additional flow paths referred to as the Left and Right Overbank Channels, respectively. The above-mentioned HEC-1 model was modified to incorporate the effects of these flow splits and the on-site flows as they impact the Left and Right Overbank Channels. The overflow from Miller Creek was modeled using the HEC-1 diversion option based on a discharge-diversion rating determined by a HEC-2 (USACE, 1990) multiple-discharge, split-flow analysis. This split flow was combined with on-site runoff and routed through a ponded storage area upstream of the railroad. Note that the flow diverted into the Left and Right Overbank Channels does not use the same crossing under the Southern Pacific Railroad as the main channel.

Pre-Countywide Analyses

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

Marin County (Unincorporated Areas)

There are 5 active USGS stream-gaging stations and roughly 14 partial-record stations on the streams in Marin County. The gaging stations are on Novato, Corte Madera, Lagunitas, and Walker Creeks. The gage on Novato Creek has the longest period of record and dates from October 1946. Values of the 10-, 2-, 1-, and 0.2-percent annual chance peak discharges were obtained from a log-Pearson Type III distribution of annual peak flow data.

The approach taken for development of discharges on streams without gages was to determine the 1-percent annual chance event peak discharge for as many streams as possible in Marin County, then to use the technique of multiple regression analysis in determining the most reliable estimate of the 1-percent annual chance peak discharges for any given area in Marin County. The streams without gages were Arroyo San Jose and Coyote, Tennessee (aka Nyan), Crest Marin, Reed, Sutton-Manor, Eskoot, Miller, and Olema Creeks.

Tidal elevations for San Pablo and Richardson Bays were taken from data at the U.S. Coast and Geodetic Survey gage at the Presidio on San Francisco Bay, with 73 years of records (U.S. Department of Commerce, 1980). Elevations for these areas were determined based on an elevation-frequency curve of the annual maximum flood levels recorded at the Presidio.

Town of Corte Madera

In view of the limitations of the rational and other methods for calculating storm runoff, a mathematical model for urban stormwater systems developed under the sponsorship of the Federal Water Quality Administration was used to determine the magnitude of fluvial and sheet flooding in the study area. This model is very versatile and is quite appropriate for use in the Town of Corte Madera. The model has not been published at this time.

Tidal elevations from two gaging stations located in close proximity to the Town of Corte Madera were used in conjunction with tidal frequency-elevation relationships developed by the USACE for the San Francisco Bay area (U.S. Department of Commerce, Tidal Bench Marks) to develop the Total-Tide Frequency Curve for this study.

Town of Fairfax

In an open-file report (USGS, 1971), S. E. Rantz, a hydrologist with the USGS, derived flood-frequency relations on the basis of streamflow records. Peak discharges were computed for several recurrence intervals up to 50 years by fitting the log-Pearson Type III distribution (Water Resources Council, 1967) to observed annual peak flows, and correlating the peak discharges with climatological and topographical parameters. According to the USGS (USGS, 1971), the most significant parameters were the drainage area and the mean annual precipitation. The relations, derived by multiple regression analysis, were of the form

$$Q_T = KA^aP^b$$

in which Q_T is peak discharge, in cubic feet per second (cfs), for a recurrence interval of T years; A is drainage area, in square miles, P is mean annual precipitation, in inches; and K, a, and b are constants.

Estimates of discharge for the 50-percent, 20-percent (5-year), 10-, 4-, and 2-percent annual chance floods were computed, by application of these regional relations, for 13 sites in the Town of Fairfax and five sites in the City of Belvedere. Estimates of the 1- and 0.2-percent annual chance floods were then obtained by logarithmic extrapolation. The discharge values for the 10-, 2-, 1-, and 0.2-percent annual chance floods were then adjusted for the effects of urbanization by methods described in the Open-File Report, Suggested Criteria for Hydrologic Design of Storm-Drainage Facilities in the San Francisco Bay Region.

City of Larkspur

A USGS stream gaging station is located on Corte Madera Creek immediately upstream of the City of Larkspur in the Town of Ross. This station has a contributing drainage area of 18.1 square miles, and a peak discharge-frequency curve as developed in 1966 as part of a study performed by the San Francisco District, USACE (USACE, 1958; USACE, 1966). The analysis was based on a log-Pearson Type III distribution of peak flows recorded between 1952 and 1965. The analysis was reviewed using additional flow data through 1971 and applying updated guidelines as outlined in the U.S. Water Resources Council Bulletin 17B (U.S. Water Resources Council, 1981). Peak discharge-frequency curves for additional downstream locations were determined by adjusting the original curve's flows based on a drainage area comparison of the known and desired locations.

Previous work of the USACE on the frequency of occurrence of high tides in the San Francisco Bay was reviewed and the 10-, 2-, 1-, and 0.2-percent annual chance high tides were established for Corte Madera Creek (USACE, 1975).

City of Mill Valley

Storm hydrographs developed by the USACE, San Francisco District (USACE, 1973), were furnished for the following locations:

1. Arroyo Corte Madera del Presidio Creek at Camino Alto
2. Arroyo Corte Madera del Presidio Creek at USGS gaging station downstream of La Goma Street
3. Arroyo Corte Madera del Presidio Creek at Gardner Street
4. Warner Creek at East Blithedale Avenue
5. Old Mill Creek at Miller Avenue
6. Reed Creek at Linden Avenue

The Cascade Dam and Reservoir on the upper Reed Creek was assumed to be nonexistent for the City of Mill Valley study. Also, storms of 3-hour duration were ignored and only 72-hour duration storms were investigated.

Overflows from Arroyo Corte Madera del Presidio Creek cause shallow flooding from 1 to 3 feet in depth. These floodflows are generally confined to street areas because the immediate overbank area that parallels the channel contains homes and businesses. In determining the flood elevation of the 1-percent annual chance event, street flows were analyzed separately from the main channel flow with adjustments made in discharge quantities in the channel proper.

A unit-hydrograph for Sutton-Manor Creek was developed by making use of basin characteristics such as drainage area, stream length, distance to center of gravity of drainage basin, channel slope, lag time, and an average S-curve hydrograph developed by the USACE, San Francisco District.

A flood hydrograph was developed for Sutton-Manor Creek at East Blithedale Avenue using the following data: (1) unit hydrograph; (2) loss rates; (3) base flows; (4) December 1955 Standard Project Storm-15-minute rainfall distribution; (5) the Freedom, 8NNW, Hollister and Stanyton Mine gage data from 0800 December 21 to 0600 December 24, 1955; (6) isohyetal map; and (7) the curve showing the relationships of the 72-hour precipitation in percent of normal annual precipitation with the drainage area.

Discharges for Ryan Creek and its subbasins were determined by proportioning areas and normal annual precipitation.

The details of the hydrologic studies are available in a hydrology report prepared by the USACE (USACE, 1969), supplemented by data submitted by the firm of Jordan/Mathis, in their February 2, 1973, report under contract to the USACE, San Francisco District (USACE, 1973).

The 6-foot 1-percent annual chance tidal elevation on Richardson Bay was determined using a U.S. Coast and Geodetic Survey Report (U.S. Department of Commerce, 1972).

City of Novato

For Novato Creek, floodflow data were based on statistical analysis of discharge records covering a 33-year period at gaging station No. 4595 (located in Novato Creek on the right bank approximately 100 feet upstream from Tamalpais Avenue bridge and 1 mile west of U.S. Highway 101) operated by the USGS. This analysis followed the standard log-Pearson Type III method as outlined by the U.S. Water Resources Council (U.S. Water Resources Council, 1981).

For Novato Creek and tributaries, peak discharges for floods of 10-, 2-, 1-, and 0.2-percent annual chance recurrence intervals were based on data developed by the USACE (USACE, 1974; USACE, 1987; USACE, 1966; USACE, 1975).

Town of Ross

Estimates of overbank flows from Corte Madera Creek downstream from Lagunitas Road were obtained by apportioning the estimated floodflows according to the conveyances of the main channel and overflow areas.

U.S. Water Resources Council criteria were used to analyze streamflow records obtained at the Town of Ross gage on Corte Madera Creek in the study area (U.S. Water Resources Council, 1981). The computed discharge for the 1-percent annual chance flood was within 2 percent of the values determining using the regional analysis of Rantz (U.S. Department of the Interior, 1971) or the method used by the USACE (USACE, 1961; USACE, 1966).

City of San Rafael

Flood hydrographs and peak discharges for the 10-, 2-, 1-, and 0.2-percent annual chance floods for streams in the City of San Rafael studied by detailed procedures were based on rainfall-runoff computations using the HEC-1 computer program (USACE, 1981). No stream-gage records are available for the streams in the City of San Rafael.

The unit-hydrographs and loss rates used in the rainfall-runoff computations were based on regional relationships developed by the USACE. Storm precipitation depths for each recurrence interval were based on rainfall statistics published by the California Department of Water Resources (State of California, 1976). Loss rates within the City of San Rafael were adjusted to account for the percentage of impervious area associated with existing urbanization within each subbasin.

Storm hydrographs for each subbasin were routed through the stream channels using the Muskingum routing technique. Flow rates in excess of channel capacities were routed overland and recombined with channel flows where appropriate.

City of Sausalito

There are no stream-gage or rainfall records in the study area in the City of Sausalito; consequently, there are no direct means to establish hydrologic relationships. It was, therefore, necessary to use synthetic relationships.

Data concerning the frequency of occurrence of high tides in San Francisco Bay have been prepared by the USACE (USACE, 1961). From these data, the 10-, 2-, 1-, and 0.2-percent annual chance tidal elevations at Sausalito were established.

The tsunami wave runup elevations for the 1- and 0.2-percent annual chance recurrence intervals were published in reports prepared for the FIA (USACE, 1975; USACE, 1978). Runup wave elevations for the 10- and 2-percent annual chance recurrence intervals were estimated by using information from an earlier report prepared for the U.S. Department of Housing and Urban Development by the USGS (U.S. Department of Housing and Urban Development, 1972). Elevations for the tides and tsunami wave runups for the selected recurrence intervals were compared, and the highest values were used in this study.

Analysis of the Coloma Drainage was based on a detailed analysis made before the construction of the storm drain and on engineering judgment.

A summary of the drainage area-peak discharge relationships for all the streams studied by detailed methods is shown in Table 5, "Summary of Discharges."

Table 5 - Summary of Discharges

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
ARROYO AVICHI					
At Novato Creek	1.78	550	770	890	1,140
ARROYO CORTE MADERA DEL PRESIDIO CREEK					
At Northwestern Pacific Railroad	6.01	1,440	2,330	2,710	3,550
At Stream Gaging Station	4.69	1,120	1,810	2,110	2,760
Downstream of La Goma Street	4.69	594	840	930	1,094
Just upstream of confluence with Warner Canyon Creek	3.62	900	1,460	1,700	2,220
Just upstream of confluence with Old Mill Creek	1.54	380	610	710	920
ARROYO SAN JOSE					
Approximately 1,800 feet downstream of	5.4	1,200	1,900	2,300	2,900

Table 5 - Summary of Discharges

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
Bel Marin Keys bridge At U.S. Highway 101	5.4	1,200	1,900	2,300	2,900
CORTE MADERA CREEK					
At U.S. Highway 101	24.7	5,500	8,000	9,000	9,700
At Bon Air Road	21.6	5,000	7,400	8,300	9,000
At Tamalpais Creek	20.2	4,800	7,100	8,000	8,700
At Tamalpais Creek culverts	N/A	N/A	N/A	N/A	N/A
Above confluence of Tamalpaid Creek	18.1	4,300	6,400	7,300	8,000
At the Town of Ross gage	18.1	4,060	6,200	6,900	8,400
CORTE MADERA CREEK (continued)					
At the City of San Anselmo/Town of Ross corporate limits	14.4	3,200	4,700	5,300	6,800
CORTE MADERA CREEK OVERFLOW					
At Tamalpais Creek Culverts	N/A	118	1,037	1,580	3,213
At Split Flow at Lagunitas Bridge	N/A	516	2,064	2,856	4,679
COYOTE CREEK					
At State Highway 1 bridge	3.48	1,240	1,860	2,110	2,630
Downstream of confluence with Tennessee Creek	3.37	1,200	1,800	2,040	2,550
Upstream of confluence with Tennessee Creek	1.56	680	1,000	1,120	1,390
At Ash Street	1.32	540	800	910	1,130
CREST MARIN CREEK					
Upstream of confluence with Tennessee Creek	0.30	110	160	180	240
DOWNTOWN DRAINAGE	0.40	185	350	*	*
ESKOOT CREEK					
At Bolinas Lagoon	1.59	666	970	1,090	1,350
At State Highway 1	1.32	540	810	910	1,130

Table 5 - Summary of Discharges

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
FAIRFAX CREEK					
Confluence with San Anselmo Creek	4.10	850	1,450	1,720	2,400
Mouth of Bothin Creek	3.40	690	1,200	1,450	2,000
White Hill School (near Town of Fairfax corporate limits)	1.80	450	770	960	1,600
FAIRFAX CREEK OVERFLOW					
Upstream of Pacheco Avenue	N/A	185	529	733	1,205
HILARITA DRAINAGE	0.14	58	140	*	*
IGNACIO CREEK					
At confluence with Arroyo San Jose	1.3	400	650	800	1,000
KITTLE CREEK					
At Sir Francis Drake Boulevard	0.28	70	135	150	290
At Walters Road	0.25	60	115	150	260
LAGUNITAS CREEK					
At Point Reyes Station Bridge	107.3	14,700	25,000	28,050	34,840
MILLER CREEK (LEVEED CHANNEL)					
At mouth	9.35	1,190	1,190	1,190	1,190
MILLER CREEK (UPSTREAM CHANNEL)					
At the Southern Pacific Railroad	9.35	1,600	2,540	2,870	3,395
MILLER CREEK – LEFT OVERBANK CHANNEL					
Approximately 830 feet upstream of the Southern Pacific Railroad	N/A	*	*	1,665	*
Approximately 1,900 feet upstream of the Southern Pacific Railroad	N/A	*	*	1,344	*
Approximately 2,550 feet upstream of the Southern Pacific Railroad	N/A	*	*	954	*
MILLER CREEK – RIGHT OVERBANK CHANNEL					
Approximately 1,160 feet	N/A	*	*	2,010	*

Table 5 - Summary of Discharges

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
upstream of the Southern Pacific Railroad					
Approximately 1,830 feet upstream of the Southern Pacific Railroad	N/A	*	*	545	*
Approximately 2,880 feet upstream of the Southern Pacific Railroad	N/A	*	*	185	*
MURPHY CREEK					
At Brookwood Lane	0.15	50	90	115	190
NOVATO CREEK					
Downstream of confluence of Arroyo Avichi	25.40	3,420	5,140	6,230	8,150
Downstream of confluence of Warner Creek	23.62	3,110	4,690	5,690	7,460
Upstream of Warner Creek	18.4	2,160	3,310	4,080	5,370
At USGS gage	18.0	2,090	3,260	3,990	5,260
At upstream corporate limits of City of Novato	13.80	1,300	2,100	2,500	3,800
Downstream of confluence of Bowman Canyon	13.7	1,690	2,680	3,280	4,300
At Stafford Dam	10.30	900	1,500	1,900	2,800
Inflow to Stafford Lake	8.4	1,330	1,980	2,340	3,060
Outflow from Stafford Lake	8.4	920	1,590	1,940	2,580
OLD MILL CREEK					
At confluence with Arroyo Corte Madera del Presidio Creek	1.85	470	750	870	1,140
OLEMA CREEK					
At Bear Valley Road Bridge	14.6	3,590	5,150	5,720	6,810
PACHECO CREEK					
At Northwestern Pacific Railroad	1.69	470	670	770	980
REED CREEK					
At Evergreen Avenue	0.84	250	380	430	540
REED DRAINAGE NO. 1	0.30	150	300	[1]	[1]
REED DRAINAGE NO. 2	0.30	150	300	[1]	[1]
ROSS CREEK					
At confluence with Corte Madera	3.00	720	1,220	1,400	2,000
At corporate limits of	2.15	500	850	990	1,500

Table 5 - Summary of Discharges

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
Town of Ross					
SAN ANSELMO CREEK					
Mouth of Fairfax Creek	9.00	1,970	3,100	3,500	4,500
Mouth of Deer Park Creek	4.96	1,080	1,780	2,100	3,000
Mouth of Wood Lane Drainage	4.19	930	1,620	1,900	2,780
Cross Section P	3.70	800	1,420	1,590	2,350
At corporate limits of Town of Fairfax	3.10	725	1,300	1,480	2,100
SAN RAFAEL CREEK					
At Grand Avenue	4.3	1,430	1,865	1,995	2,500
At Ritter Street	2.3	740	720	690	810
At Lincoln Avenue	2.1	530	500	410	400
At Lindero Street	1.8	640	670	690	600
At B Street	1.7	750	905	1,090	1,050
At C Street	1.6	675	700	740	840
At D Street	1.5	725	1,165	1,350	1,740
Upstream end of 2nd Street culvert	1.3	400	705	830	1,100
SUTTON-MANOR CREEK					
At mouth	1.00	300	535	625	765
SYCAMORE PARK OVERFLOW					
Downstream of La Goma Street	N/A	526	970	1,180	1,665
TENNESSEE CREEK					
Upstream of confluence with Coyote Creek	1.81	550	840	960	1,220
Upstream of confluence with Crest Marin Creek	1.51	440	680	780	980
VINEYARD CREEK					
Downstream of confluence Of Unnamed Creek	1.69	490	700	810	1,040
Upstream of confluence of Unnamed Creek	1.43	370	530	610	790
At mouth	2.60	580	830	960	1,230
At confluence of Unnamed Tributary to Vineyard Creek	0.26	120	170	200	250
WARNER CANYON CREEK					
At confluence with Arroyo Corte Madera del Presidio	0.98	210	330	390	500

Table 5 - Summary of Discharges

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
WARNER CREEK					
Upstream of confluence of Novato Creek	5.18	1,260	1,800	2,080	2,680
Downstream of confluence of Wilson Creek	4.47	1,080	1,540	1,770	2,280
WILSON CREEK					
At mouth	1.88	520	750	860	1,100
At Mill Road	1.42	470	680	780	1,000

[1]Reduced flow value is due to capacity restriction resulting in sheet flow away from channel

*Data Not Available

The stillwater elevations have been determined for the 10-, 2-, 1-, and 0.2-percent annual chance floods for the flooding sources studied by detailed methods and are summarized in Table 6, "Summary of Stillwater Elevations, Open Pacific Coast." Table 6a, "Summary of Stillwater Elevations, Sheltered Waters," summarizes the Stillwater elevations for the 10-, 2-, 1-, and 0.2-percent annual chance floods for the flooding sources studied by detailed methods for Richardson, San Francisco, San Pablo, and San Rafael Bays.

Table 6 – Summary of Stillwater Elevations, Open Pacific Coast

	ELEVATION (feet NAVD88)			
FLOODING SOURCE AND LOCATION	10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
PACIFIC OCEAN				
Bolinas/Stinson Beach	7.7	8.1	8.2	8.5
BOLINAS LAGOON				
Eskoot Creek Entrance	7.7	8.1	8.2	8.5

Table 6a – Summary of Stillwater Elevations, Sheltered Waters

FLOODING SOURCE AND LOCATION			ELEVATION (feet NAVD88)			
STATION	LONGITUDE	LATITUDE	10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
B1	-122.492	38.109	8.7	9.0	9.9	11.0
B2	-122.488	38.106	8.7	9.0	10.0	11.0
B3	-122.486	38.102	8.7	9.0	10.0	11.1
B4	-122.484	38.099	8.7	9.0	10.0	11.1
B5	-122.485	38.095	8.6	9.0	10.0	11.2
B6	-122.485	38.088	8.6	9.0	10.0	11.2
B7	-122.485	38.081	8.6	9.0	10.0	11.2
B8	-122.485	38.079	8.6	9.0	10.0	11.2
B9	-122.484	38.074	8.6	9.0	9.9	11.2
B10	-122.487	38.068	8.6	8.9	9.9	11.1
B11	-122.488	38.064	8.6	8.9	9.9	11.1
B12	-122.491	38.059	8.6	8.9	9.9	11.1

Table 6a – Summary of Stillwater Elevations, Sheltered Waters

FLOODING SOURCE AND LOCATION			ELEVATION (feet NAVD88)			
STATION	LONGITUDE	LATITUDE	10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
B13	-122.492	38.054	8.6	8.9	9.9	11.1
B14	-122.492	38.049	8.5	8.9	9.9	11.1
B15	-122.495	38.043	8.5	8.9	9.9	11.0
B16	-122.497	38.034	8.5	8.9	9.8	11.0
B17	-122.498	38.026	8.5	8.9	9.8	11.0
B18	-122.497	38.022	8.5	8.9	9.8	11.0
B19	-122.498	38.018	8.5	8.9	9.8	11.0
B20	-122.498	38.016	8.5	8.9	9.8	10.9
B21	-122.494	38.016	8.5	8.8	9.8	10.9
B22	-122.490	38.015	8.5	8.8	9.8	11.0
B23	-122.486	38.012	8.5	8.8	9.8	11.0
B24	-122.482	38.009	8.5	8.8	9.8	11.0
B25	-122.480	38.007	8.5	8.8	9.8	11.0
B26	-122.477	38.006	8.5	8.9	9.8	11.0
B27	-122.476	38.007	8.5	8.9	9.8	11.0
B28	-122.475	38.006	8.5	8.8	9.8	11.0
B29	-122.474	38.006	8.5	8.8	9.8	11.0
B30	-122.472	38.005	8.5	8.8	9.8	11.0
B31	-122.471	38.005	8.5	8.8	9.8	11.0
B32	-122.470	38.004	8.5	8.8	9.8	10.9
B33	-122.468	38.003	8.5	8.8	9.8	11.0
B34	-122.466	38.004	8.5	8.8	9.8	11.0
B35	-122.465	38.004	8.5	8.8	9.8	11.0
B36	-122.464	38.003	8.5	8.8	9.8	11.0
B37	-122.463	38.004	8.5	8.8	9.8	10.9
B38	-122.462	38.003	8.5	8.8	9.8	10.9
B39	-122.461	38.002	8.5	8.8	9.8	11.0
B40	-122.461	38.001	8.5	8.8	9.8	11.0
B41	-122.460	37.999	8.4	8.8	9.7	10.9
B42	-122.458	37.998	8.4	8.8	9.7	10.9
B43	-122.456	37.997	8.4	8.8	9.7	10.9
B44	-122.455	37.996	8.4	8.8	9.7	10.9
B45	-122.454	37.994	8.4	8.8	9.7	10.9
B46	-122.453	37.993	8.4	8.8	9.7	10.9
B47	-122.450	37.991	8.4	8.8	9.7	10.9
B48	-122.450	37.990	8.4	8.8	9.7	10.9
B49	-122.448	37.987	8.4	8.7	9.7	10.8
B50	-122.449	37.984	8.4	8.7	9.6	10.8
B51	-122.450	37.983	8.4	8.7	9.6	10.7
B52	-122.455	37.981	8.4	8.7	9.6	10.8
B53	-122.456	37.980	8.4	8.7	9.6	10.8
B54	-122.459	37.981	8.4	8.7	9.7	10.8
B55	-122.463	37.981	8.4	8.8	9.7	10.8
B56	-122.464	37.982	8.4	8.7	9.6	10.8

Table 6a – Summary of Stillwater Elevations, Sheltered Waters

FLOODING SOURCE AND LOCATION			ELEVATION (feet NAVD88)			
STATION	LONGITUDE	LATITUDE	10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
B57	-122.464	37.983	8.4	8.7	9.6	10.8
B58	-122.466	37.985	8.4	8.7	9.6	10.8
B59	-122.469	37.984	8.4	8.7	9.6	10.8
B60	-122.473	37.983	8.4	8.8	9.7	10.7
B61	-122.474	37.981	8.4	8.8	9.7	10.7
B62	-122.475	37.978	8.4	8.8	9.7	10.7
B63	-122.476	37.975	8.4	8.7	9.7	10.8
B64	-122.482	37.973	8.4	8.7	9.7	10.8
B65	-122.485	37.970	8.4	8.8	9.7	10.8
B66	-122.488	37.971	8.4	8.8	9.7	10.8
B67	-122.491	37.971	8.4	8.8	9.7	10.8
B68	-122.495	37.968	8.4	8.7	9.7	10.8
B69	-122.493	37.966	8.4	8.8	9.7	10.8
B70	-122.490	37.962	8.4	8.7	9.7	10.8
B71	-122.490	37.958	8.4	8.7	9.6	10.8
B72	-122.489	37.956	8.4	8.8	9.7	10.8
B73	-122.488	37.951	8.4	8.7	9.6	10.8
B74	-122.487	37.949	8.4	8.7	9.7	10.8
B75	-122.485	37.946	8.4	8.7	9.7	10.8
B76	-122.482	37.946	8.4	8.7	9.6	10.8
B77	-122.482	37.941	8.4	9.2	9.7	10.8
B78	-122.485	37.940	8.4	9.2	9.7	10.8
B79	-122.488	37.938	8.4	9.2	9.7	10.8
B80	-122.494	37.939	8.4	9.3	9.7	10.9
B81	-122.498	37.941	8.4	9.3	9.7	10.9
B82	-122.502	37.943	8.4	9.3	9.7	10.9
B83	-122.506	37.944	8.4	9.3	9.7	10.9
B84	-122.505	37.941	8.4	9.3	9.7	10.9
B85	-122.505	37.940	8.4	9.3	9.7	10.9
B86	-122.506	37.938	8.4	9.3	9.7	10.9
B87	-122.505	37.936	8.4	9.3	9.7	10.9
B88	-122.505	37.933	8.4	9.2	9.7	10.9
B89	-122.503	37.930	8.4	9.2	9.7	10.8
B90	-122.503	37.927	8.4	9.2	9.7	10.8
B91	-122.501	37.926	8.4	9.2	9.7	10.8
B92	-122.498	37.925	8.4	9.2	9.7	10.8
B93	-122.496	37.923	8.4	9.2	9.7	10.8
B94	-122.495	37.922	8.4	9.2	9.7	10.8
B95	-122.492	37.921	8.4	9.2	9.7	10.8
B96	-122.490	37.921	8.4	9.2	9.7	10.8
B97	-122.488	37.921	8.3	9.2	9.6	10.8
B98	-122.485	37.920	8.3	9.2	9.6	10.8
B99	-122.481	37.918	8.3	9.2	9.6	10.8
B100	-122.474	37.914	8.3	9.2	9.6	10.8

Table 6a – Summary of Stillwater Elevations, Sheltered Waters

FLOODING SOURCE AND LOCATION			ELEVATION (feet NAVD88)			
STATION	LONGITUDE	LATITUDE	10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
B101	-122.474	37.911	8.3	9.2	9.6	10.9
B102	-122.477	37.907	8.3	9.2	9.6	10.9
B103	-122.477	37.905	8.3	9.2	9.6	10.9
B104	-122.474	37.904	8.3	9.2	9.6	10.9
B105	-122.471	37.902	8.3	9.2	9.6	10.9
B106	-122.469	37.902	8.3	9.2	9.6	10.9
B107	-122.467	37.898	8.3	9.2	9.6	10.9
B108	-122.462	37.897	8.3	9.2	9.6	10.9
B109	-122.459	37.895	8.3	9.2	9.6	10.9
B110	-122.456	37.894	8.3	9.2	9.6	10.9
B111	-122.453	37.894	8.3	9.2	9.6	10.9
B112	-122.449	37.894	8.3	9.2	9.6	10.9
B113	-122.446	37.890	8.3	9.2	9.6	10.9
B114	-122.444	37.887	8.3	9.2	9.6	10.9
B115	-122.438	37.881	8.3	9.1	9.6	10.9
B116	-122.442	37.881	8.3	9.2	9.7	11.0
B117	-122.444	37.878	8.3	9.2	9.6	11.0
B118	-122.446	37.875	8.3	9.2	9.7	11.0
B119	-122.449	37.875	8.3	9.2	9.7	11.0
B120	-122.450	37.873	8.3	9.2	9.6	11.0
B121	-122.452	37.872	8.3	9.2	9.7	11.1
B122	-122.454	37.873	8.3	9.2	9.7	11.1
B123	-122.456	37.873	8.3	9.2	9.7	11.1
B124	-122.459	37.872	8.3	9.2	9.7	11.2
B125	-122.461	37.874	8.3	9.2	9.7	11.2
B126	-122.463	37.873	8.3	9.2	9.7	11.2
B127	-122.463	37.871	8.3	9.2	9.7	11.2
B128	-122.461	37.868	8.3	9.2	9.7	11.1
B129	-122.458	37.864	8.3	9.2	9.7	11.1
B130	-122.460	37.863	8.3	9.2	9.7	11.1
B131	-122.467	37.868	8.2	9.2	9.7	11.1
B132	-122.472	37.873	8.3	9.2	9.7	11.2
B133	-122.474	37.876	8.3	9.2	9.7	11.2
B134	-122.473	37.880	8.3	9.2	9.7	11.2
B135	-122.471	37.881	8.3	9.2	9.7	11.2
B136	-122.472	37.883	8.3	9.2	9.7	11.2
B137	-122.475	37.886	8.3	9.2	9.7	11.2
B138	-122.479	37.889	8.3	9.2	9.7	11.2
B139	-122.482	37.890	8.3	9.2	9.7	11.2
B140	-122.482	37.891	8.3	9.2	9.8	11.2
B141	-122.486	37.892	8.3	9.3	9.8	11.3
B142	-122.488	37.895	8.3	9.3	9.8	11.3
B143	-122.490	37.895	8.3	9.3	9.8	11.3
B144	-122.494	37.894	8.3	9.3	9.8	11.3

Table 6a – Summary of Stillwater Elevations, Sheltered Waters

FLOODING SOURCE AND LOCATION			ELEVATION (feet NAVD88)			
STATION	LONGITUDE	LATITUDE	10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
B145	-122.500	37.894	8.3	9.3	9.8	11.3
B146	-122.502	37.895	8.3	9.3	9.8	11.3
B147	-122.504	37.895	8.3	9.3	9.8	11.3
B148	-122.501	37.891	8.3	9.3	9.8	11.3
B149	-122.500	37.888	8.3	9.3	9.8	11.3
B150	-122.498	37.883	8.3	9.2	9.8	11.3
B151	-122.496	37.879	8.3	9.2	9.7	11.3
B152	-122.499	37.878	8.3	9.2	9.8	11.3
B153	-122.503	37.880	8.3	9.3	9.8	11.4
B154	-122.508	37.884	8.3	9.3	9.8	11.4
B155	-122.511	37.888	8.3	9.3	9.8	11.5
B156	-122.515	37.886	8.3	9.3	9.8	11.5
B157	-122.519	37.888	8.3	9.3	9.8	11.5
B158	-122.521	37.891	8.3	9.3	9.8	11.5
B159	-122.523	37.891	8.3	9.3	9.8	11.5
B160	-122.520	37.885	8.3	9.3	9.8	11.5
B161	-122.520	37.884	8.3	9.3	9.8	11.5
B162	-122.518	37.883	8.3	9.3	9.8	11.5
B163	-122.514	37.882	8.3	9.3	9.8	11.4
B164	-122.513	37.879	8.3	9.3	9.8	11.4
B165	-122.510	37.877	8.3	9.3	9.8	11.4
B166	-122.505	37.875	8.3	9.3	9.8	11.3
B167	-122.504	37.872	8.3	9.2	9.8	11.3
B168	-122.500	37.872	8.3	9.2	9.8	11.3
B169	-122.496	37.867	8.3	9.2	9.7	11.2
B170	-122.490	37.864	8.3	9.2	9.7	11.2
B171	-122.485	37.860	8.3	9.2	9.7	11.2
B172	-122.482	37.859	8.2	9.2	9.7	11.2
B173	-122.479	37.857	8.2	9.2	9.6	11.1
B174	-122.479	37.855	8.2	9.1	9.6	11.1
B175	-122.479	37.852	8.2	9.1	9.6	11.0
B176	-122.480	37.849	8.2	9.1	9.6	11.0
B177	-122.478	37.847	8.2	9.1	9.6	11.0
B178	-122.477	37.844	8.2	9.1	9.6	11.0
B179	-122.475	37.840	8.2	9.1	9.6	11.0
B180	-122.472	37.835	8.2	9.1	9.6	10.9
B181	-122.476	37.834	8.1	9.0	9.5	10.8
B182	-122.479	37.831	8.1	9.0	9.5	10.8
B183	-122.479	37.827	8.1	9.0	9.5	10.8
B184	-122.423	37.854	8.3	9.2	9.7	11.1
B185	-122.443	37.859	8.3	9.2	9.7	11.1
B186	-122.435	37.869	8.3	9.2	9.7	11.0
B187	-122.424	37.870	8.3	9.2	9.7	11.1
B188	-122.466	37.965	8.4	8.7	9.6	10.7

Table 6a – Summary of Stillwater Elevations, Sheltered Waters

FLOODING SOURCE AND LOCATION			ELEVATION (feet NAVD88)			
STATION	LONGITUDE	LATITUDE	10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
B189	-122.466	37.964	8.4	8.8	9.7	10.8
B190	-122.469	37.965	8.4	8.7	9.6	10.7
B191	-122.473	37.967	8.4	8.7	9.6	10.7
B192	-122.470	37.964	8.4	8.8	9.7	10.8
B193	-122.473	37.965	8.4	8.8	9.7	10.8
B194	-122.474	37.966	8.4	8.8	9.7	10.8

* Data Not Available

3.2 Hydraulic Analyses

Analyses of the hydraulic characteristics of flooding from the source studied were carried out to provide estimates of the elevations of floods of the selected recurrence intervals. Users should be aware that flood elevations shown on the FIRM represent rounded whole-foot elevations and may not exactly reflect the elevations shown on the Flood Profiles or in the Floodway Data tables in the FIS report. For construction and/or floodplain management purposes, users are encouraged to use the flood elevation data presented in this FIS in conjunction with the data shown on the FIRM.

Cross sections were determined from topographic maps and field surveys. All bridges, dams, and culverts were field surveyed to obtain elevation data and structural geometry. All topographic mapping used to determine cross sections is referenced in Section 4.1.

Locations of selected cross sections used in the hydraulic analyses are shown on the Flood Profiles (Exhibit 1). For stream segments for which a floodway was computed (Section 4.2), selected cross section locations are also shown on the FIRM (Exhibit 2).

The hydraulic analyses for this FIS were based on unobstructed flow. The flood elevations shown on the profiles are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail.

All elevations are referenced to the North American Vertical Datum of 1988 (NAVD 88). To obtain up-to-date elevation information on National Geodetic Survey (NGS) bench marks shown on this map, please contact the Information Services Branch of the NGS at (301) 713-3242, or visit their website at www.ngs.noaa.gov. Map users should seek verification of non-NGS bench mark monument elevations when using these elevations for construction or floodplain management purposes.

Revised Analysis

For the March 17, 2014 revision of the countywide FIS, updated hydraulic analyses on the Arroyo Corte Madera del Presidio Creek, Corte Madera Creek, Corte Madera Creek Overflow, Fairfax Creek, Fairfax Creek Overflow, Old Mill Creek, San Anselmo Creek, San Anselmo Creek Overflow, Sycamore Park Overflow, and Warner Canyon Creek was performed for the 10-, 2-, 1-, and 0.2-percent annual chance flood events using the USACE HEC-RAS Version 4.1.0 hydraulic model (USACE, 2008).

The HEC-RAS hydraulic models were executed under the assumption of subcritical flow to produce the most conservative water surface elevations. Mean Higher-High Water was used as the downstream boundary condition for Arroyo Corte Madera del Presidio Creek and Corte Madera Creek. Normal depth was used as the downstream boundary condition for Warner Canyon Creek. The slope was measured as the bed slope between the two downstream cross sections. All other reaches used HEC-RAS split flow optimization to match energy grade elevations at the junction of main stream and overflow branches. Model results were compared to available flood damage information from the December 2005 storm provided by Marin County and the City of Mill Valley.

First Time Countywide Analysis

Information on the methods used to determine hydraulic relationships for the streams restudied as part of the first time countywide FIS is shown below.

For the first revision of the countywide FIS, data collected following a December 2005 flood in Marin County demonstrated that flood hazard data presented in the prior FISs and FIRMs along San Anselmo and Corte Madera Creeks in the Towns of San Anselmo and Ross were inaccurate. The event also demonstrated that some flood hazard data presented in the FIS and FIRM along Sleepy Hollow Creek and Sorich Drainage in the Town of San Anselmo were inaccurate as well. As such, an approximate analysis of flooding was conducted and some portions are included in this FIS and FIRM. The December 2005 flood was considered to be approximately a 1-percent annual chance flood event. The approximate analysis used topographic information with a 5-foot contour interval and property damage reports for the affected area, all provided by Marin County, to map the approximate area of the 1-percent annual chance flood within the subject area. Based on these data, approximate limits of 1-percent annual chance flooding were depicted for and are shown on the FIRM. Those reaches of the flood profiles for Sleepy Hollow Creek, and Sorich Drainage that lie within areas designated as approximate flood hazard areas were removed from the FIS.

The cross-sectional data used to model Miller Creek and the Left and Right Overbank Channels were taken from field surveys and topographic mapping at a scale of 1:4,800, with a contour interval of 2 feet (Towil, Inc., 1991).

Water-surface elevations of the floods of the selected recurrence intervals were computed using HEC-2. Between cross sections, the 1-percent annual chance floodplain boundary was interpolated using topographic mapping at a scale of 1:4,800, with a contour interval of 2 feet (I. O. Swartz, Inc., undated). The elevations of the ponded areas located upstream of the Southern Pacific Railroad were based on the maximum stage calculated in the storage routing performed in the above-mentioned HEC-1 model.

Channel roughness factors (Manning's "n") used in the hydraulic analysis of Miller Creek were based on field observations and guidelines published by the USGS (U.S. Department of the Interior, 1987).

Levees are along both banks of the revised portion of Miller Creek. These levees do not have sufficient freeboard to be certified as providing protection from the 1- percent annual chance flood event. Therefore, with- and without-levee analyses were performed. It was necessary to perform a split-flow analysis for both the with and without-levee conditions to determine the amount of flow that escapes into the Left and Right Overbank Channels.

Pre-Countywide Analyses

Each incorporated community within, and the unincorporated areas of, Marin County, has a previously printed FIS report except the City of Belvedere. The hydraulic analyses described in those reports have been compiled and are summarized below.

Marin County (Unincorporated Areas)

The hydraulic information developed during a 1972 FIS for Marin County (U.S. Department of Housing and Urban Development, 1972) was reevaluated and expanded by using more up-to-date topographic information. Aerial photographs were utilized to determine changes in topography due to urbanization.

Water-surface elevations of floods of the selected recurrence intervals were computed through use of the USACE HEC-2 step-backwater computer program (USACE, 1990).

Cross-sectional data for streams studied in detail were obtained from existing topographic maps, channel improvement plans, bridge drawings, or field surveys. Cross sections were located at close intervals above and below bridges and culverts to compute the significant backwater effects of these structures.

The starting water-surface elevations for Reed and Sutton-Manor Creeks were taken from the FIS for the City of Mill Valley (U.S. Department of Housing and Urban Development, 1978). The starting water-surface elevations for Novato Creek and Arroyo San Jose were taken from the FIS for the City of Novato (FEMA, 1984).

The Eskoot and Lagunitas Creek starting water-surface elevations were set by tidal elevations. The Olema Creek starting water-surface elevation was based on coincident flows at the confluence with Lagunitas Creek. The Crest Marin and

Tennessee Creek starting water-surface elevations were based on coincident flows at their confluences with Coyote Creek.

For streams studied by approximate methods, flooded areas were determined using Manning's equation and normal-depth techniques. The approximate flooding areas of the bays were determined using the highest estimated tide taken from local tidal bench marks.

Shallow flooding on detailed-study streams was hand calculated by determining the 1-percent annual chance discharge, determining the channel capacity, and finding the amount of overflow. Using Manning's equation, a relationship between depth and hydraulic radius was computed, and the width and depth of the flow were determined.

For the large ponding areas on Arroyo San Jose, approximately 1,000 feet downstream of Bel Marin Keys, the water-surface elevation was determined using a flood-routing analysis.

Tidal elevations for the 10-, 2-, 1-, and 0.2-percent annual chance events were taken from USGS gage records from the Presidio of San Francisco (U.S. Department of the Interior, 1975), in conjunction with mean higher high-water and highest estimated tide values for specific locations. The frequencies for mean higher high-water and highest estimated tide for local tide gages are assumed to be equal to those at the Presidio gage.

The effects of tsunami-induced flooding were considered based on previous studies (U.S. Department of Housing and Urban Development, 1975; U.S. Department of Housing and Urban Development, 1978) and found to be insignificant in the northern end of San Francisco Bay.

Town of Corte Madera

A hydraulic study conducted by the USACE indicates that a flood having a 1-percent annual chance recurrence interval in Corte Madera Creek will not create an inundation problem as severe as that created by the estimated 1-percent annual chance tide in San Francisco Bay (USACE, "Comprehensive Survey of San Francisco Bay and Tributaries (Tidal Stage Frequency and Tidal Reference Plans").

The major flooding of the Town of Corte Madera considered is due to tidal flooding from San Francisco Bay. Water-surface elevations for the town were developed from the Total-Tide Frequency Curve.

Town of Fairfax

Water-surface elevations were computed using two culvert surveys, 54 stream cross sections obtained by field surveys, and the USGS computer programs E-431 (USGS, 1976) and A-526 (USGS, 1969) for the detailed study on Fairfax and San Anselmo Creeks.

After review and analysis of the data collected on Deer Park Creek and Wood Lane Drainage, it was concluded that computations of reliable flood profiles was not possible. Data was sufficient, however, to indicate that flooding would occur in the form of sheetflow and that it would be initiated outside the Town of Fairfax corporate limits. The same data were then used to estimate the average depth of inundation.

Culvert computations and overflow sections obtained in the field were used with the estimated 1-percent annual chance discharge for the Bothin Creek Drainage, the only area to be studied by approximate methods. Information obtained from Town of Fairfax officials and local residents was also used.

The base (1-percent annual chance) flow will be contained within the Fairfax Creek channel from the Town of Fairfax corporate limits to a point just upstream from Sir Francis Drake Boulevard. The base flow will exceed the capacity of the culvert at Sir Francis Drake Boulevard and sheetflow will occur along the west bank upstream from the culvert and along the east bank of the creek from the culvert to a point approximately 300 feet downstream from Banchero Way. All overflow will have returned to the channel at this point. Upstream from the dam, north of Westbrae Drive, the flow is confined by high ground along Olema Drive on the west and by a recently built apartment complex on the east. Overflow will occur along the left bank beginning approximately 500 feet upstream from the dam. Inundation of the apartments lining the creek in this area will occur; overflow will return to the channel downstream from the dam. Below the dam, overflow on the right bank along Olema Drive is outside the corporate limits until it reaches Westbrae Drive, where minor flooding occurs down to Hawthorne Court and returns to Fairfax Creek as sheetflow along Bothin Road upstream from Marin Road. The channel from the dam to the confluence with Bothin Creek will contain the base (1-percent annual chance) flow.

The 1-percent annual chance flow will cause inundation of areas adjacent to Fairfax Creek in the reach from Bothin Creek to Bolinas Avenue, with the more severe flooding occurring downstream from Scenic Road. The Bolinas Avenue-Sherman Avenue culvert conveys lesser flows directly to San Anselmo Creek, but the 1-percent annual chance flow will exceed the culvert capacity. The overflow will pass through the Town of Fairfax downtown business and residential area downstream from Bolinas Avenue as sheetflow before entering San Anselmo Creek.

Base flows will exceed the capacity of culverts along Deer Park Creek and Wood Lane Drainage, and the resultant overland flows will pass to San Anselmo Creek as sheetflow. In the lower reaches of Wood Lane Drainage, overflow to Deer Park Creek will occur between Wood Lane and Creek Road. The increased flood flows in this portion of Deer Park Creek will increase the estimated depth of inundation along Porteous Avenue and Creek Road from Ivy Lane to San Anselmo Creek.

City of Larkspur

Topographic data for channel cross sections were obtained from existing plans and topographic mapping, supplemented with aerial photogrammetric and field survey data as necessary (Cartwright Aerial Surveys, 1970; Herman D. Ruth & Associates, City of Larkspur General Plan).

The starting water-surface elevation for Corte Madera Creek at the confluence with San Francisco Bay was based on a mean higher high water elevation of 5.69 feet NAVD 88.

The results of the backwater analysis indicate that in most areas, a flood having a 1-percent annual chance recurrence interval in Corte Madera Creek will not create an inundation problem as severe as that created by the estimated 1-percent annual chance tide.

Areas subject to tidal inundation include all areas lower than the 1-percent annual chance tide, which are not protected by an adequate, maintained levee system. The lagoon bounded by Riviera Circle connects by culvert to Corte Modera Creek and was included in the tidal zone.

In general, most of the City of Larkspur surrounding Corte Madera Creek is designated as tidal Zone AE on the Flood Insurance Rate Maps (FIRMs). Portions of the city may be subject to very shallow sheet flow during a 1-percent annual chance flood as floodwaters from Corte Madera Ridge flow toward the creek.

City of Mill Valley

In the downtown area of the City of Mill Valley, structures occupy the overbank area of Arroyo Corte Madera del Presidio Creek, or the air space above the channel. While floodflows may not be sufficient to remove these structures, the damages could contribute to the debris that would block downstream culverts and bridges. Also, the main streamflows would be forced into city streets as sheet flow.

City of Novato

Flood elevations along the shoreline of San Pablo Bay for the 10-, 2-, 1-, and 0.2-percent annual chance events are presented in Table 5 and were obtained from a statistical analysis of available tide gage data at the entrance of the Petaluma River (USACE, 1984). The elevations reflect the increase of the elevation in San Pablo Bay due to storm surge and include the contribution of the astronomical tide. The results do not include any contribution to the elevation along the shoreline due to wave action or wave runup.

Town of Ross

Starting water-surface elevations for the backwater analyses on Ross Creek were estimated using normal-depth calculations. Culvert computations were used to initiate analyses on Kittle Creek and Murphy Creek.

Town of San Anselmo

Starting elevations for the backwater analysis on San Anselmo Creek (called Corte Madera Creek in downstream reaches) were obtained using the current stage-discharge relation for the USGS gaging station on Corte Madera Creek in the adjacent Town of Ross and extended using slope-conveyance computations. Starting elevations for the backwater computations on Sleepy Hollow Creek were estimated using water-surface elevations computed for San Anselmo Creek at its junction with Sleepy Hollow Creek. Profiles for Sorich Drainage, which did not lend themselves to automatic computation, were developed using culvert computations, slope-conveyance computations, and available topographic maps (U.S. Water Resources Council, 1967) augmented with field surveys.

The extent of shallow sheetflow from Laurel, Greenfield, and Red Hill Drainages was based upon culvert capacities as computed in the storm drainage report (Hoffman and Albritton, 1975), together with available topographic maps (State of California, 1961), field-surveyed cross sections and topography, and information furnished by city officials and local residents.

City of San Rafael

Topographic data for channel cross sections were obtained from existing plans and topographic mapping, supplemented with aerial photogrammetric and field survey data as necessary (San Rafael Redevelopment Agency, 1977).

No flood profiles were drawn for Gallinas Creek and the South Fork Gallinas Creek where the study water-surface elevations are entirely controlled by tidal flooding from San Pablo Bay. Similarly, no profile was drawn for San Rafael Creek downstream of Grand Avenue (San Rafael Canal) where the elevations are controlled by San Rafael Bay.

The shallow flooding zones (Zone AH) adjacent to San Rafael Creek were caused by overflows from the channel near D Street which flow west along the channel. The ponding areas were caused by the constricted section between A and B Streets and by the channel levees near the Southern Pacific Railroad. The channel levees cause the water to pond up to elevation 11 before it can spill back into the channel near Lincoln Avenue.

In general, most of the City of San Rafael is designated as either shaded or unshaded Zone X on the FIRMs. The limited capacity of the storm drainage system will subject a large portion of downtown City of San Rafael to shallow sheet flow during the 1-percent annual chance flood as floodwaters in excess of the storm drain capacity flow down the streets.

Approximately 6,500 feet of levee may be vulnerable to wave overtopping in the City of San Rafael. Therefore, wave runup and overtopping were investigated as possible sources of tidal flooding.

The analysis was based on Saville and Caldwell's methodology for overtopping rate estimations as illustrated in the Shore Protection Manual published by the

USACE (USACE, 1977). The 1-percent annual chance tide elevation and a design windspeed of 50 mph were assumed in the analysis. This resulted in an estimated wind wave of 5.0 feet significant wave height and 4.5 seconds in wave periodicity.

The levee has varying sections and side slopes. Outside levee slopes vary from approximately 3:1 to 5:1, and wave runup varies from elevation 17 feet NAVD 88 to elevation 14 feet NAVD 88, respectively. Wave runup would overtop the levee over the entire length. The estimated volume of water overtopping the levee would exceed the floodplain volume below an elevation of 9 feet NAVD 88 and the 1-percent annual chance floodplain would fill to an elevation of 9 feet NAVD 88. The low bank elevations along the San Rafael Canal would limit the water-surface elevation to the 1-percent annual chance tide elevation.

The tidal floodplain within the levee was not considered to be subject to significant wave action. There would be insufficient fetch to develop wind waves of 3 feet or more, and 1-percent annual chance flood depths would generally be insufficient to maintain a significant wave.

Areas subject to tidal inundation include all areas lower than the 1-percent annual chance (USACE, 1975), which are not protected by an adequate, maintained levee system.

Town of Tiburon

Longitudinal profiles for the stream channels and the estimated 10-, 2-, 1-, and 0.2-percent annual chance floods were developed from culvert surveys using Program A526 (culvert analysis), from hydraulic computations utilizing 49 channel cross sections, and from Program C649 (backwater analysis), along with slope-conveyance computations. Ten additional cross sections were used to define the approximate extent of sheet flow areas.

The first section studied of the Tiburon Downtown drainage represents a pump capacity of 35 cfs. A pond and pump system contains the 10-percent annual chance flood runoff; but the 2-, 1-, and 0.2-percent annual chance storms cause sheet flow within the Cities of Tiburon and Belvedere, and therefore, are not shown on the profiles. Also, the 2-, 1-, and 0.2-percent annual chance floods from the Tiburon drainage are not represented on the profiles because they overflow within Tiburon and Belvedere via Tiburon Boulevard.

Tidal elevation-frequency data for the Town of Tiburon were obtained from a frequency curve of observed annual maximum tides at San Francisco (Ft. Point), prepared by the USACE and transferred to the Town of Tiburon area on the basis of data compiled by the U.S. Coast and Geodetic Survey (USACE, 1961).

The flood profile for Belvedere Downtown Drainage does not include data for the 2-, 1-, or 0.2-percent annual chance flood events as backwater from the Lagoon Road culvert causes waters from these events to flow southerly along Tiburon Boulevard and eventually to Belvedere Lagoon in the vicinity of Cove Road.

Roughness factors (Manning's "n") used in the hydraulic computations were chosen by engineering judgment and were based on field observations of the streams and floodplain areas. Roughness factors for all streams studied by detailed methods are shown in Table 7, “Manning’s “n” Values.”

Table 7 - Manning’s “n” Values

Stream or Community	Channel “n”	Overbank “n”
Corte Madera Creek	0.015-0.055	0.062-0.200
Coyote Creek		
Downstream of earthen channel	0.040	0.080
Upstream of concrete channel	0.014	*
Crest Marin Creek		
Mouth to upstream of Poplar Street	0.060	0.100
Maple Street to Poplar Street	0.060	0.100
Kittle Creek	0.016-0.035	0.020-0.035
Lagunitas Creek		
Station 0	0.035	0.035
Station 7,838	0.035	0.035
Station 9,958	0.035	0.035
Station 11,330	0.035	0.035
Station 12,809	0.045	0.060
Station 14,885	0.045	0.060
Station 15,876	0.060	0.070
Miller Creek		
Stations 400 to 33,373	0.040	0.040-0.050
Murphy Creek	0.035-0.060	*
Olema Creek		
Station 0	0.035	0.035
Station 570	0.070	0.070
Station 2,458	0.050	0.050
Station 2,730	0.050	0.050
Station 10,240	0.080	0.080
Reed Creek	0.060	0.100
Ross Creek	0.030-0.040	[1]
Tennessee Creek		
Mouth to upstream entrance of Concourse Bridge	0.040	0.070
Entrance of Concourse Bridge to upstream end	0.050	0.070
Town of Fairfax	0.025-0.080	0.020-0.150
City of Larkspur	0.020-0.060	0.030-0.050
City of Novato	0.020-0.055	0.014-0.100
Town of San Anselmo	0.030-0.075	0.075-0.200
City of San Rafael	0.015-0.060	0.020-0.050

*Data not available
[1]Does not apply because flows contained by channel

Behind-Levee Analyses

Some flood hazard information presented in prior FIRMs and in prior FIS reports for Marin County and its incorporated communities was based on flood protection provided by levees. Based on the information available and the mapping standards of the NFIP at the time that the prior FISs and FIRMs were prepared, FEMA accredited the levees as providing protection from the flood that has a 1-percent chance of being equaled or exceeded in any given year. For FEMA to continue to accredit the identified levees with providing protection from the base flood, the levees must meet the criteria of the Code of Federal Regulations, Title 44, Section 65.10 (44 CFR 65.10), titled "Mapping of Areas Protected by Levee Systems."

On August 22, 2005, FEMA issued "Procedure Memorandum No. 34 – Interim Guidance for Studies Including Levees." The purpose of the memorandum was to help clarify the responsibility of community officials or other parties seeking recognition of a levee by providing information identified during a study/mapping project. Often, documentation regarding levee design, accreditation, and the impacts on flood hazard mapping is outdated or missing altogether. To remedy this, Procedure Memorandum No. 34 provides interim guidance on procedures to minimize delays in near-term studies/mapping projects, to help our mapping partners properly assess how to handle levee mapping issues.

While documentation related to 44 CFR 65.10 is being compiled, the release of a more up-to-date FIRM for other parts of a community or county may be delayed. To minimize the impact of the levee recognition and certification process, FEMA issued "Procedure Memorandum No. 43 – Guidelines for Identifying Provisionally Accredited Levees" on March 16, 2007. These guidelines allow issuance of the FIS and FIRM while levee owners or communities compile full documentation required to show compliance with 44 CFR 65.10. The guidelines also explain that a FIRM can be issued while providing the communities and levee owners with a specified timeframe to correct any maintenance deficiencies associated with a levee and to show compliance with 44 CFR 65.10.

FEMA contacted the communities within Marin County to obtain data required under 44 CFR 65.10 to continue to show the levees as providing protection from the flood that has a 1-percent annual chance of being equaled or exceeded in any given year.

FEMA understood that it may take time to acquire and/or assemble the documentation necessary to fully comply with 44 CFR 65.10. Therefore, FEMA put forth a process to provide the communities with additional time to submit all the necessary documentation. For a community to avail itself of the additional time, it had to sign an agreement with FEMA. Levees for which such agreements were signed are shown on the final effective FIRM as providing protection from the flood that has a 1-percent annual chance of being equaled or exceeded in any given year and labeled as a Provisionally Accredited Levee (PAL). Communities have two years from the date of FEMA's initial coordination to submit to FEMA final accreditation data for all PALs. Following receipt of final accreditation data, FEMA will revise the FIS and FIRM as warranted.

FEMA coordinated with the local communities, the USACE, and other organizations to compile a list of levees that exist within Marin County. Table 8 lists all levees shown on the FIRM, to include PALs, for which corresponding flood hazard revisions were made.

Table 8 - List of Levees

Community	Flood Source	Levee Inventory Identification Number	USACE Levee
City of Novato	Novato Creek	0, 10, and 33	No
Marin County (Unincorporated Areas)	San Antonio Creek	11 and 12	No
City of Novato	Pacheco Creek	8	No
Marin County (Unincorporated Areas)	Miller Creek	5, 6, 7, 30, 31, and 194	No
City of San Rafael	Gallinas Creek	29	No
City of Larkspur and Marin County (Unincorporated Areas)	Corte Madera Creek	15, 20, 22, 23, 24, 25, 150, and 153	Yes
Town of Corte Madera	Unnamed Stream to Corte Madera Creek	20 and 122	No
Marin County (Unincorporated Areas)	Richardson Bay	3	No
City of Novato	Petaluma River	13 and 14	No
City of San Rafael	San Rafael Bay	217	No
Marin County (Unincorporated Areas)	Coyote Creek	34	No

Approximate analyses of “behind levee” flooding were conducted for all the levees in Table 8 to indicate the extent of the “behind levee” floodplains. The methodology used in these analyses is discussed below.

Levees 0, 10, and 33 are located along Novato Creek. Levees 5, 6, 7, 30, 31, and 194 are located along Miller Creek. Levee 34 is along Coyote Creek. Based upon the FIS and topographic information from the USGS, approximate areas of flooding in the event of failure of the levees were determined based on engineering judgment and designated as such as no accreditation data were provided.

Levees 11 and 12 are located along the San Antonio Creek. Levee 29 is located along Gallinas Creek. Levees 20 and 122 are located along an unnamed stream to Corte Madera Creek. Levee 3 is located along Richardson Bay. Levees 13, 14, and 33 are located along Petaluma River. Based upon the FIS and topographic information from the USGS, areas of flooding in the event of failure of the levees were determined. These floodplains were designated as having a 1-percent annual chance flood elevation consistent with the adjacent flood hazards, which dominate flooding in the area, as no accreditation data were provided.

Levee 8 is located along Pacheco Creek. The levee is fully accredited. According to the new detailed coastal analyses for the Marin County San Francisco Bay shoreline, sufficient freeboard is maintained above the 1-percent annual chance flood elevation.

Levee 217 is located along the San Rafael Bay. Based upon the FIS, topographic information from the USGS as well as from Merrick & Company, an approximate area of flooding in the event of failure of levee was determined based on engineering judgment and designated as such as no accreditation data were provided.

The elevation-probability distribution for swell waves followed a similar development. Stillwater was defined only from wave setup convoluted with astronomical tide. The frequency of offshore wave height and wave period from the northwest and southwest was determined from available data (Meteorology International, Inc., Deep-Water Wave Statistics for the California Coast) and routed shoreward with the wave-tracking model. The runup elevation at each beach transect was calculated using Hunt's and Stoa's methods.

Tsunami plus astronomical tide elevations having 1- and 0.2-percent annual chance recurrence intervals have been published (USACE, 1978; USACE, 1974; USACE, 1979), and for this analysis, the complete magnitude-frequency relationship was defined from supporting that the events are independent.

For Bolinas Lagoon, storm-generated components of the coastal flood hazard were evaluated by a three-step analysis. The first step determined the magnitude and frequency of storm surge, or the super-elevation of the water level above the astronomical tide that is caused by low barometric pressure and by wind stresses. The second step convoluted storm-surge probabilities with astronomical tide characteristics to define the stillwater elevation and frequency relation. Finally, wave impacts were defined and added to stillwater elevations.

Storm surge from Bolinas Lagoon was defined using the same methods employed in the study of the Pacific coast (James R. Pagenkopf, 1976; U.S. Department of Commerce, 1944-1983; U.S. Department of Commerce, 1955-1983).

Because of inlet constrictions, Bolinas Lagoon was assumed to be sheltered from the influence of offshore storm-generated waves, but the magnitudes of locally generated wind waves were investigated using methods from the Shore Protection Manual (USACE, 1977). Based on wind magnitude and frequency data, measured fetch lengths and beach profiles, the wave heights were found to be generally less than 3 feet and to provide only limited runup above the stillwater elevation. Hence, wave action was considered insignificant to the flood hazard from Bolinas Lagoon (Ott Water Engineers, Inc., 1984).

3.3 Coastal Hazard Analyses for the May 4, 2009, Countywide FIS

For the Pacific Ocean, swell-wave and wind-wave frequency and magnitude components were determined by a two-step process. The first step defined a stillwater elevation that included the effects of astronomical tide, storm surge, and wave setup. The second step determined wave runup above the stillwater elevation onto the beach.

Storm surge from the Pacific Ocean was defined by a two-dimensional finite-element computer model (James R. Pagenkopf, 1976). Applicability of the model had been tested by using long-term climatic records for San Francisco (U.S. Department of Commerce, 1944-1983) to synthesize a long-term record of storm-surge hydrographs for San Francisco Bay. The close match of the synthesized data to available long-term tidal records confirmed the usability of the model for California coastal conditions. For the Pacific Ocean, the model synthesized a record from 1955 to 1983 of storm surge, windspeed, wind direction, and barometric pressure data, as determined from Three-Hourly North American Surface Weather Maps (U.S. Department of Commerce, 1955-1983). The frequency and magnitude of storm surges were defined from the synthesized storm-surge record.

The effect of storm surge was combined with astronomical tide and wave setup to define the stillwater elevation needed to evaluate the wind-wave runup. Characteristics of astronomical tide in Marin County could be reliably defined from previous studies (U.S. Department of Commerce, 1945-1983); and were convoluted with storm surge (USACE, 1977). The magnitude of wind-wave setup was calculated by an iterative process coupled with the wave runup calculations.

Runup of wind waves was evaluated by first determining the deepwater wave conditions from both the southwest and northwest using the 1955-to-1983 climatic data and methods described in the Shore Protection Manual. A wave-tracking model (R. S. Dobson, 1967) then transformed the deepwater waves as they traveled toward the shoreline on the basis of bathymetry and beach profiles. Beach transects along the coast provided a generalized representation of the beach profiles that control the magnitude of wave runup. In coastal-study areas, beach transects were oriented perpendicular to the shoreline and were strategically located along the shore to represent reaches with similar characteristics (see Figure 1, "Transect Location Map." Data were primarily obtained from offshore bathymetry maps supplemented with 1978 USACE survey data (USACE, California Coast Storm Damage, Winter 1977-1978). Table 9 provides a listing of the transect locations, and Figure 2 presents a sample transect. The wave runup along sloping sandy beaches was computed by Hunt's method (I. J. Hunt, 1959); at obstructions, it was computed by Stoa's method (USACE, 1978).

Table 9 - Transect Locations

Study Area	Transect Number	Location
Bolinas/Stinson Beach	1	In Bolinas, from coastline and east along Terrace Street.
	2	In Stinson Beach, from the coastline, northeast to Seadrift Road, and stopping approximately 400 feet from the road's northwest end.
	3	In Stinson Beach, from the ocean edge, northeast along residence 284 Seadrift Road to the southwest shore of the lagoon.
	4	From the ocean edge in Stinson Beach, northeast along 194 Seadrift Road to the edge of the lagoon.
	5	From the ocean edge in Stinson Beach, northeast along Walla Vista to Calle del Arroyo.
	6	From the water's edge in Stinson Beach along Calle del Occidente to its terminus and beyond the five houses.
	7	From the water's edge in Stinson Beach along Calles del Pradero to its intersection with State Highway 1.

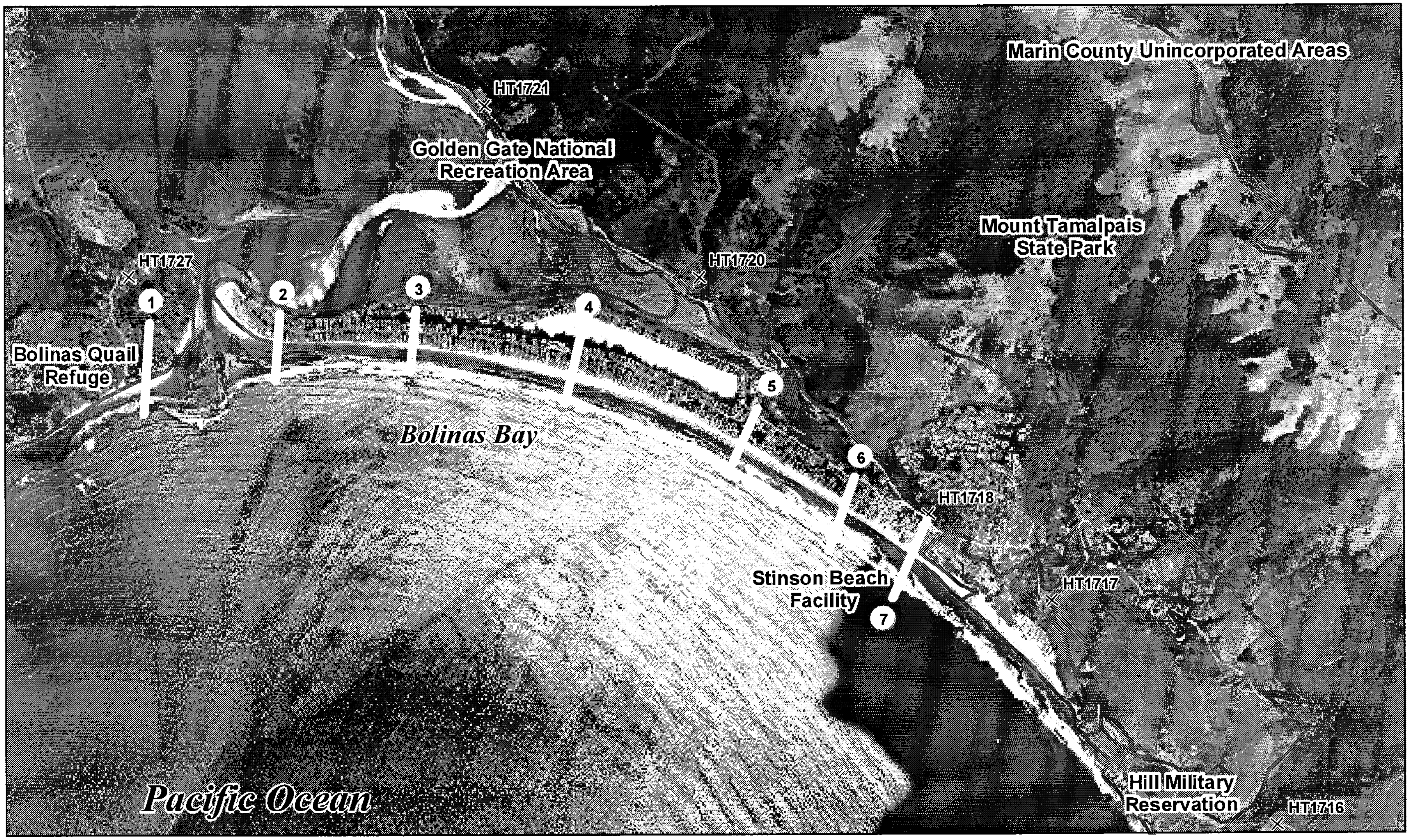

FIGURE 1

FEDERAL EMERGENCY MANAGEMENT AGENCY

MARIN COUNTY, CA
AND INCORPORATED AREAS

0 1,000 2,000 4,000 6,000 8,000 Feet

TRANSECT LOCATION MAP

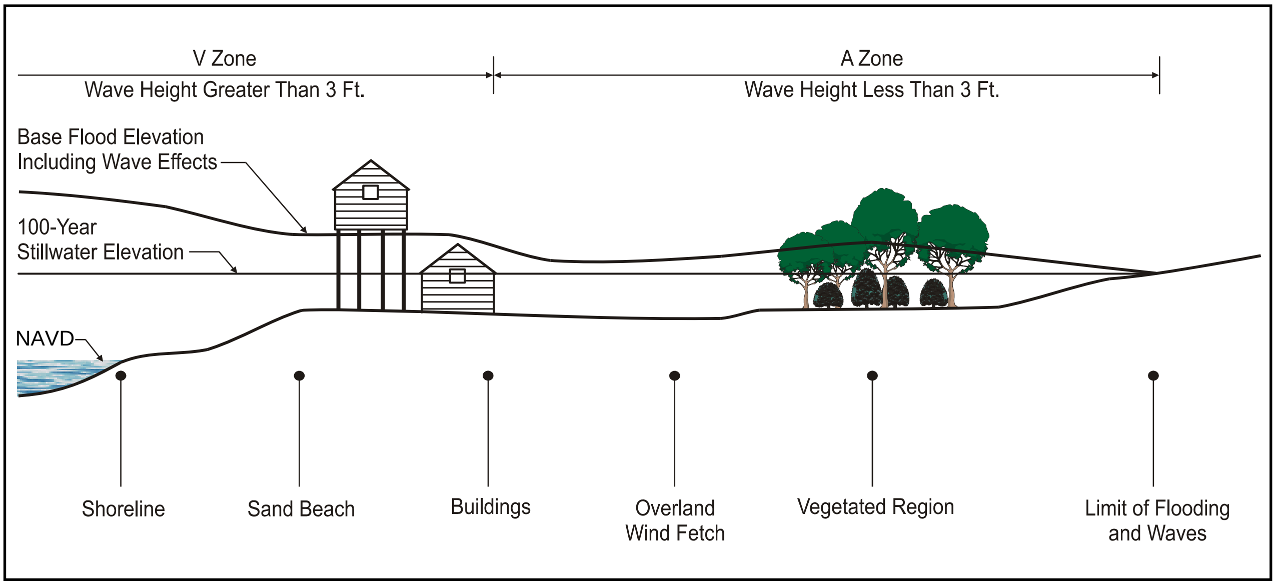

FIGURE 2 - TRANSECT SCHEMATIC

3.4 Coastal Analyses for the <date> Revision to the Countywide FIS

For San Francisco Bay, storm surge, swell-wave and wind-waves were modeled at a regional scale using numerical models to deterministically predict water levels and wave conditions in the bay (DHI, 2011). Coastal flooding hazards were then evaluated with one-dimensional (1D) transect-based models.

The MIKE 21 Flow Model (HD) and MIKE 21 Spectral Wave (SW) model developed by DHI Water & Environment were used for the regional surge and wave modeling. The hydrodynamic model included the effects of tide, storm surge, and riverine discharge. The wave modeling was performed in two separate models, one for locally developing wind-waves and one for Pacific Ocean swell propagating into San Francisco Bay through the Golden Gate. The models synthesized water level and wave condition information for the 31 year period from 1973 to 2004. The frequency and magnitude of storm surge and wave heights was derived statistically from the synthesized 31 year record.

Water level and wave information from the regional hydrodynamic and wave models was used as input to the 1D flood hazard analyses. Wave setup, runup, overtopping, and overland wave propagation were analyzed at representative transects. Transects are shown on the FIRM panels and depicted in the three San Francisco Bay Shoreline Transect Location Maps (see Figure 3). For the study portion south of the I-580/Richmond-San Rafael Bridge, bathymetric information was derived from USACE dredging surveys and NOAA/National Ocean Service (NOS) Geophysical Data System (GEODAS) bathymetric data. In areas where the two datasets overlapped, the USACE data was given priority. For the study portion north of the I-580/Richmond-San Rafael Bridge, bathymetric datasets originally collected by NOAA and used in the 2011 DHI model (DHI, 2011) were merged with the topography to develop a bathymetric TIN for elevations less than 0 ft NAVD88.

Overland wave propagation modeling, using FEMA's Wave Height Analysis for Flood Insurance Studies (WHAFIS) model, Version 4 (FEMA, 1988; Divoky, 2007), was performed for transects with gently sloping profiles where the prevailing ground is inundated by the stillwater flood level alone. WHAFIS solves the wave action conservation equation and incorporates wind-generated wave growth and dissipation by marsh grasses, rigid vegetation, and buildings.

Wave runup was calculated for transects with coastal armoring or steeply sloping ground profiles in the vicinity of the flooded shoreline. Runup was calculated using one of three methods, depending on shoreline characteristics. The Direct Integration Method (FEMA, 2005) was used to calculate runup for transects with natural, gently sloping (m < 0.125) profiles. The Technical Advisory Committee for Water Retaining Structures (TAW) (van der Meer, 2002) method was used for shorelines with shore protection structures and steeply sloping (m ≥0.125) natural shorelines. The Shore Protection Manual (SPM) method (USACE, 1984) was used to calculate wave runup on vertical walls. The total runup elevation is also referred to as the total water level (TWL). Annual TWL maxima were selected from the 31 years (1973-2003) of hindcast data, and the generalized extreme value (GEV) distribution was employed to determine the 1-percent-annual-chance TWL from the annual maxima at each transect. Wave overtopping was evaluated for transects where the runup elevation exceeded the structure or bluff crest. Table 10, "San Francisco Bay Shoreline Transect Data for <date> Revision," provides a listing of the transect locations.

Table 10 - San Francisco Bay Shoreline Transect Data for <date> Revision

Transect	XY Coordinates		Stillwater Elevation (feet NAVD 88)[1]				Zone	BFE
	Longitude	Latitude	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance		
B1	-122.492	38.109	8.7	9.0	9.9	11.0	AE	10 - 11
B2	-122.488	38.106	8.7	9.0	10.0	11.0	AE	11 - 13
B3	-122.486	38.102	8.7	9.0	10.0	11.1	VE AE	12 11 - 13
B4	-122.484	38.099	8.7	9.0	10.0	11.1	VE AE	12 10 - 11
B5	-122.485	38.095	8.6	9.0	10.0	11.2	VE AE	12 10 - 12
B6	-122.485	38.088	8.6	9.0	10.0	11.2	VE AE	12 10 - 11
B7	-122.485	38.081	8.6	9.0	10.0	11.2	VE AE	12[2] 10 - 11
B8	-122.485	38.079	8.6	9.0	10.0	11.2	VE AE	12 10 - 11

Table 10 - San Francisco Bay Shoreline Transect Data for <date> Revision

Transect	XY Coordinates		Stillwater Elevation (feet NAVD 88)[1]				Zone	BFE
	Longitude	Latitude	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance		
B9	-122.484	38.074	8.6	9.0	9.9	11.2	VE AE	12 10 - 11
B10	-122.487	38.068	8.6	8.9	9.9	11.1	VE AE	11 - 12 10 - 11
B11	-122.488	38.064	8.6	8.9	9.9	11.1	VE AE	11 - 12 10 - 11
B12	-122.491	38.059	8.6	8.9	9.9	11.1	VE AE	12 10 - 11
B13	-122.492	38.054	8.6	8.9	9.9	11.1	VE AE	12 10 - 11
B14	-122.492	38.049	8.5	8.9	9.9	11.1	AE	10 - 11
B15	-122.495	38.043	8.5	8.9	9.9	11.0	VE AE	12 10 - 11
B16	-122.497	38.034	8.5	8.9	9.8	11.0	VE AE	12 10 - 11
B17	-122.498	38.026	8.5	8.9	9.8	11.0	VE AE	12 10 - 11
B18	-122.497	38.022	8.5	8.9	9.8	11.0	VE AE	11 10 - 11
B19	-122.498	38.018	8.5	8.9	9.8	11.0	VE AE	11 10 - 11
B20	-122.498	38.016	8.5	8.9	9.8	10.9	VE AE	10 10
B21	-122.494	38.016	8.5	8.8	9.8	10.9	VE AE	10 10
B22	-122.490	38.015	8.5	8.8	9.8	11.0	VE AE	10 10
B23	-122.486	38.012	8.5	8.8	9.8	11.0	VE AE	10 10
B24	-122.482	38.009	8.5	8.8	9.8	11.0	VE AE	10 10
B25	-122.480	38.007	8.5	8.8	9.8	11.0	VE AE	10 10
B26	-122.477	38.006	8.5	8.9	9.8	11.0	VE AE	10[2] 10
B27	-122.476	38.007	8.5	8.9	9.8	11.0	VE	15[2]
B28	-122.475	38.006	8.5	8.8	9.8	11.0	VE	13[2]
B29	-122.474	38.006	8.5	8.8	9.8	11.0	AE	10[2]
B30	-122.472	38.005	8.5	8.8	9.8	11.0	AE	10[2]
B31	-122.471	38.005	8.5	8.8	9.8	11.0	VE	13[2]
B32	-122.470	38.004	8.5	8.8	9.8	10.9	VE	13[2]

Table 10 - San Francisco Bay Shoreline Transect Data for <date> Revision

Transect	XY Coordinates		Stillwater Elevation (feet NAVD 88)[1]				Zone	BFE
	Longitude	Latitude	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance		
B33	-122.468	38.003	8.5	8.8	9.8	11.0	VE AE	13[2] 13[2]
B34	-122.466	38.004	8.5	8.8	9.8	11.0	VE	14[2]
B35	-122.465	38.004	8.5	8.8	9.8	11.0	AE	11[2]
B36	-122.464	38.003	8.5	8.8	9.8	11.0	VE AE	10[2] 10[2]
B37	-122.463	38.004	8.5	8.8	9.8	10.9	VE	12[2]
B38	-122.462	38.003	8.5	8.8	9.8	10.9	VE	15[2]
B39	-122.461	38.002	8.5	8.8	9.8	11.0	VE	13[2]
B40	-122.461	38.001	8.5	8.8	9.8	11.0	VE AE	11[2] 11[2]
B41	-122.460	37.999	8.4	8.8	9.7	10.9	AE	11[2]
B42	-122.458	37.998	8.4	8.8	9.7	10.9	VE	15[2]
B43	-122.456	37.997	8.4	8.8	9.7	10.9	VE	16[2]
B44	-122.455	37.996	8.4	8.8	9.7	10.9	AE	10[2]
B45	-122.454	37.994	8.4	8.8	9.7	10.9	AE	10[2]
B46	-122.453	37.993	8.4	8.8	9.7	10.9	VE AE	12[2] 12[2]
B47	-122.450	37.991	8.4	8.8	9.7	10.9	VE	12[2]
B48	-122.450	37.990	8.4	8.8	9.7	10.9	AE	10[2]
B49	-122.448	37.987	8.4	8.7	9.7	10.8	VE AE	14[2] 14[2]
B50	-122.449	37.984	8.4	8.7	9.6	10.8	VE	14[2]
B51	-122.450	37.983	8.4	8.7	9.6	10.7	VE	15[2]
B52	-122.455	37.981	8.4	8.7	9.6	10.8	VE	16[2]
B53	-122.456	37.980	8.4	8.7	9.6	10.8	VE	18[2]
B54	-122.459	37.981	8.4	8.7	9.7	10.8	VE	12[2]
B55	-122.463	37.982	8.4	8.8	9.7	10.8	VE	12[2]
B56	-122.464	37.982	8.4	8.7	9.6	10.8	VE AE	14[2] 10[2]
B57	-122.464	37.983	8.4	8.7	9.6	10.8	VE AE	12[2] 10
B58	-122.466	37.985	8.4	8.7	9.6	10.8	AE	10
B59	-122.469	37.984	8.4	8.7	9.6	10.8	VE AE	12[2] 10
B60	-122.473	37.983	8.4	8.8	9.7	10.7	VE AE	12[2] 10
B61	-122.474	37.981	8.4	8.8	9.7	10.7	VE AE	12[2] 10
B62	-122.475	37.978	8.4	8.8	9.7	10.7	VE AE	12[2] 10

Table 10 - San Francisco Bay Shoreline Transect Data for <date> Revision

Transect	XY Coordinates		Stillwater Elevation (feet NAVD 88)[1]				Zone	BFE
	Longitude	Latitude	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance		
B63	-122.476	37.975	8.4	8.7	9.7	10.8	AE	10[2]
B64	-122.482	37.973	8.4	8.7	9.7	10.8	AE AE	12[2] 11
B65	-122.485	37.970	8.4	8.8	9.7	10.8	VE	13[2]
B66	-122.488	37.971	8.4	8.8	9.7	10.8	VE	13[2]
B67	-122.491	37.971	8.4	8.8	9.7	10.8	AE	10 - 11[2]
B68	-122.495	37.968	8.4	8.7	9.7	10.8	AE	10
B69	-122.493	37.966	8.4	8.8	9.7	10.8	AE	10[2]
B70	-122.490	37.962	8.4	8.7	9.7	10.8	VE AE	12[2] 10 - 12[2]
B71	-122.490	37.958	8.4	8.7	9.6	10.8	AE AE	12 10
B72	-122.489	37.956	8.4	8.8	9.7	10.8	AE	10 - 11[2]
B73	-122.488	37.951	8.4	8.7	9.6	10.8	AE	10 - 12[2]
B74	-122.487	37.949	8.4	8.7	9.7	10.8	AE	10 - 11[2]
B75	-122.485	37.946	8.4	8.7	9.7	10.8	AE	10
B76	-122.482	37.946	8.4	8.7	9.6	10.8	VE AE	10 10
B77	-122.482	37.941	8.4	9.2	9.7	10.8	VE	14[2]
B78	-122.485	37.940	8.4	9.2	9.7	10.8	VE	11[2]
B79	-122.488	37.938	8.4	9.2	9.7	10.8	VE	13[2]
B80	-122.494	37.939	8.4	9.3	9.7	10.9	AE AE	11[2] 10
B81	-122.498	37.941	8.4	9.3	9.7	10.9	AE	11[2]
B82	-122.502	37.943	8.4	9.3	9.7	10.9	AE	10[2]
B83	-122.506	37.944	8.4	9.3	9.7	10.9	AE	11[2]
B84	-122.505	37.941	8.4	9.3	9.7	10.9	AE	10-11
B85	-122.505	37.940	8.4	9.3	9.7	10.9	AE	10-11
B86	-122.506	37.938	8.4	9.3	9.7	10.9	AE	10-11
B87	-122.505	37.936	8.4	9.3	9.7	10.9	VE AE	11 10
B88	-122.505	37.933	8.4	9.2	9.7	10.9	VE AE	11 10
B89	-122.503	37.930	8.4	9.2	9.7	10.8	VE AE	11 10
B90	-122.503	37.927	8.4	9.2	9.7	10.8	AE	10
B91	-122.501	37.926	8.4	9.2	9.7	10.8	AE	10
B92	-122.498	37.925	8.4	9.2	9.7	10.8	AE	10
B93	-122.496	37.923	8.4	9.2	9.7	10.8	AE	10
B94	-122.495	37.922	8.4	9.2	9.7	10.8	AE	10
B95	-122.492	37.921	8.4	9.2	9.7	10.8	AE	10

Table 10 - San Francisco Bay Shoreline Transect Data for <date> Revision

Transect	XY Coordinates		Stillwater Elevation (feet NAVD 88)[1]				Zone	BFE
	Longitude	Latitude	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance		
B96	-122.490	37.921	8.4	9.2	9.7	10.8	AE	10
B97	-122.488	37.921	8.3	9.2	9.6	10.8	VE	10[2]
B98	-122.485	37.920	8.3	9.2	9.6	10.8	VE AE	12[2] 10
B99	-122.481	37.918	8.3	9.2	9.6	10.8	VE AE	11[2] 10
B100	-122.474	37.914	8.3	9.2	9.6	10.8	VE AE	12[2] 10
B101	-122.474	37.911	8.3	9.2	9.6	10.9	VE AE	12[2] 10
B102	-122.477	37.907	8.3	9.2	9.6	10.9	AE	11[2]
B103	-122.477	37.905	8.3	9.2	9.6	10.9	AE	12[2]
B104	-122.474	37.904	8.3	9.2	9.6	10.9	VE	12[2]
B105	-122.471	37.902	8.3	9.2	9.6	10.9	AE	10[2]
B106	-122.469	37.902	8.3	9.2	9.6	10.9	VE	13[2]
B107	-122.467	37.898	8.3	9.2	9.6	10.9	AE AE	10[2] 10
B108	-122.462	37.897	8.3	9.2	9.6	10.9	VE	11[2]
B109	-122.459	37.895	8.3	9.2	9.6	10.9	AE	10[2]
B110	-122.456	37.894	8.3	9.2	9.6	10.9	VE	11[2]
B111	-122.453	37.894	8.3	9.2	9.6	10.9	VE	12[2]
B112	-122.449	37.894	8.3	9.2	9.6	10.9	VE	13[2]
B113	-122.446	37.890	8.3	9.2	9.6	10.9	VE	12[2]
B114	-122.444	37.887	8.3	9.2	9.6	10.9	VE	15[2]
B115	-122.438	37.881	8.3	9.1	9.6	10.9	VE	13
B116	-122.442	37.881	8.3	9.2	9.7	11.0	AE AE	10[2] 10
B117	-122.444	37.878	8.3	9.2	9.6	11.0	VE	14[2]
B118	-122.446	37.875	8.3	9.2	9.7	11.0	VE	15[2]
B119	-122.449	37.875	8.3	9.2	9.7	11.0	VE	13[2]
B120	-122.450	37.873	8.3	9.2	9.6	11.0	VE	14[2]
B121	-122.452	37.872	8.3	9.2	9.7	11.1	VE	12[2]
B122	-122.454	37.873	8.3	9.2	9.7	11.1	VE	12[2]
B123	-122.456	37.873	8.3	9.2	9.7	11.1	VE AE	13[2] 10
B124	-122.459	37.872	8.3	9.2	9.7	11.2	VE	12[2]
B125	-122.461	37.874	8.3	9.2	9.7	11.2	VE AE	12[2] 10
B126	-122.463	37.873	8.3	9.2	9.7	11.2	VE AE	12[2] 10

Table 10 - San Francisco Bay Shoreline Transect Data for <date> Revision

Transect	XY Coordinates		Stillwater Elevation (feet NAVD 88)[1]				Zone	BFE
	Longitude	Latitude	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance		
B127	-122.463	37.871	8.3	9.2	9.7	11.2	VE AE	12[2] 10
B128	-122.461	37.868	8.3	9.2	9.7	11.1	VE	13[2]
B129	-122.458	37.864	8.3	9.2	9.7	11.1	VE	16[2]
B130	-122.460	37.863	8.3	9.2	9.7	11.1	VE	13[2]
B131	-122.467	37.868	8.2	9.2	9.7	11.1	VE	15[2]
B132	-122.472	37.873	8.3	9.2	9.7	11.2	VE	13[2]
B133	-122.474	37.876	8.3	9.2	9.7	11.2	AE	11[2]
B134	-122.473	37.880	8.3	9.2	9.7	11.2	AE AE	10[2] 10
B135	-122.471	37.881	8.3	9.2	9.7	11.2	AE AE	11[2] 10
B136	-122.472	37.883	8.3	9.2	9.7	11.2	AE AE	11[2] 10
B137	-122.475	37.886	8.3	9.2	9.7	11.2	AE	12[2]
B138	-122.479	37.889	8.3	9.2	9.7	11.2	AE	12[2]
B139	-122.482	37.890	8.3	9.2	9.7	11.2	VE	13[2]
B140	-122.482	37.891	8.3	9.2	9.8	11.2	AE	11[2]
B141	-122.486	37.892	8.3	9.3	9.8	11.3	AE	11[2]
B142	-122.488	37.895	8.3	9.3	9.8	11.3	AE	11[2]
B143	-122.490	37.895	8.3	9.3	9.8	11.3	AE	10-11
B144	-122.494	37.894	8.3	9.3	9.8	11.3	VE	13[2]
B145	-122.500	37.894	8.3	9.3	9.8	11.3	AE AE	11[2] 10
B146	-122.502	37.895	8.3	9.3	9.8	11.3	AE	10-11
B147	-122.504	37.895	8.3	9.3	9.8	11.3	AE	10
B148	-122.501	37.891	8.3	9.3	9.8	11.3	AE	10
B149	-122.500	37.888	8.3	9.3	9.8	11.3	VE AE	11[2] 10
B150	-122.498	37.883	8.3	9.2	9.8	11.3	AE AE	10[2] 10
B151	-122.496	37.879	8.3	9.2	9.7	11.3	VE	11[2]
B152	-122.499	37.878	8.3	9.2	9.8	11.3	VE	12[2]
B153	-122.503	37.880	8.3	9.3	9.8	11.4	VE	12[2]
B154	-122.508	37.884	8.3	9.3	9.8	11.4	AE	12[2]
B155	-122.511	37.888	8.3	9.3	9.8	11.5	AE	10
B156	-122.515	37.886	8.3	9.3	9.8	11.5	AE	11[2]
B157	-122.519	37.888	8.3	9.3	9.8	11.5	AE	10
B158	-122.521	37.891	8.3	9.3	9.8	11.5	AE	10[2]
B159	-122.523	37.891	8.3	9.3	9.8	11.5	AE	10
B160	-122.520	37.885	8.3	9.3	9.8	11.5	AE	10

Table 10 - San Francisco Bay Shoreline Transect Data for <date> Revision

Transect	XY Coordinates		Stillwater Elevation (feet NAVD 88)[1]				Zone	BFE
	Longitude	Latitude	10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance		
B161	-122.520	37.884	8.3	9.3	9.8	11.5	AE	10
B162	-122.518	37.883	8.3	9.3	9.8	11.5	AE	10
B163	-122.514	37.882	8.3	9.3	9.8	11.4	AE	10
B164	-122.513	37.879	8.3	9.3	9.8	11.4	AE	10
B165	-122.510	37.877	8.3	9.3	9.8	11.4	AE	10
B166	-122.505	37.875	8.3	9.3	9.8	11.3	AE AE	10[2] 10
B167	-122.504	37.872	8.3	9.2	9.8	11.3	AE	11[2]
B168	-122.500	37.872	8.3	9.2	9.8	11.3	AE	10
B169	-122.496	37.867	8.3	9.2	9.7	11.2	AE	19[2]
B170	-122.490	37.864	8.3	9.2	9.7	11.2	AE	10[2]
B171	-122.485	37.860	8.3	9.2	9.7	11.2	VE	11[2]
B172	-122.482	37.859	8.2	9.2	9.7	11.2	AE	11[2]
B173	-122.479	37.857	8.2	9.2	9.6	11.1	VE	11[2]
B174	-122.479	37.855	8.2	9.1	9.6	11.1	VE	11[2]
B175	-122.479	37.852	8.2	9.1	9.6	11.0	VE	11[2]
B176	-122.480	37.849	8.2	9.1	9.6	11.0	VE	13[2]
B177	-122.478	37.847	8.2	9.1	9.6	11.0	VE	15[2]
B178	-122.477	37.844	8.2	9.1	9.6	11.0	VE	17[2]
B179	-122.475	37.840	8.2	9.1	9.6	11.0	VE	14[2]
B180	-122.472	37.835	8.2	9.1	9.6	10.9	VE	17[2]
B181	-122.476	37.834	8.1	9.0	9.5	10.8	VE	18[2]
B182	-122.479	37.831	8.1	9.0	9.5	10.8	VE	22[2]
B183	-122.479	37.827	8.1	9.0	9.5	10.8	VE	13[2]
B184	-122.423	37.854	8.3	9.2	9.7	11.1	VE	20[2]
B185	-122.443	37.859	8.3	9.2	9.7	11.1	VE	20[2]
B186	-122.435	37.869	8.3	9.2	9.7	11.0	AE	12[2]
B187	-122.424	37.870	8.3	9.2	9.7	11.1	VE	13[2]
B188	-122.466	37.965	8.4	8.7	9.6	10.7	VE	12[2]
B189	-122.466	37.964	8.4	8.8	9.7	10.8	VE	17[2]
B190	-122.470	37.965	8.4	8.7	9.6	10.7	VE	12[2]
B191	-122.473	37.967	8.4	8.7	9.6	10.7	VE	10[2]
B192	-122.470	37.964	8.4	8.8	9.7	10.8	VE	14[2]
B193	-122.473	37.965	8.4	8.8	9.7	10.8	VE	13[2]
B194	-122.474	37.966	8.4	8.8	9.7	10.8	VE	11[2]

[1]North American Vertical Datum of 1988

[2]Wave runup elevation

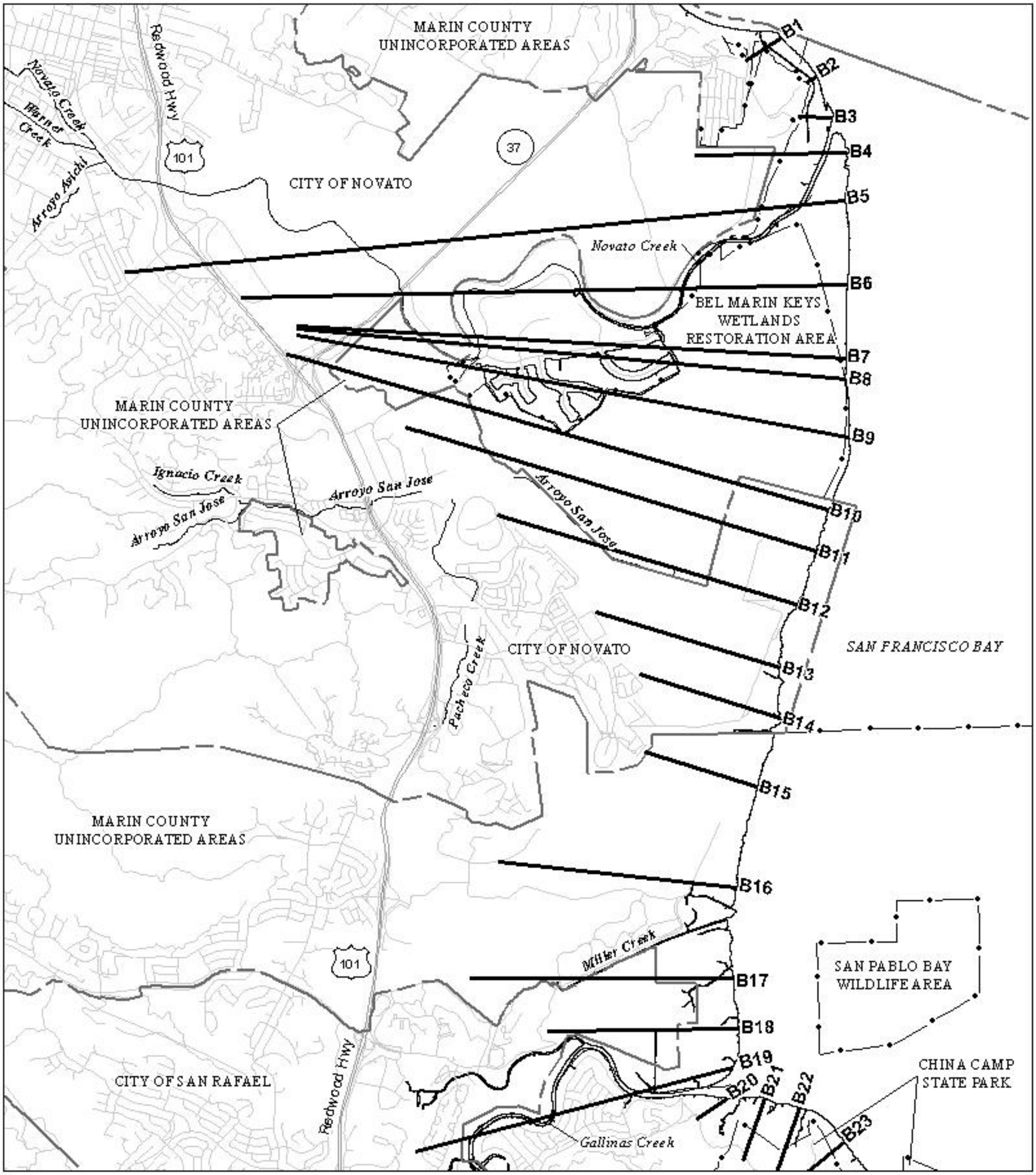

FIGURE 3

FEDERAL EMERGENCY MANAGEMENT AGENCY

MARIN COUNTY, CALIFORNIA AND INCORPORATED AREAS

0 0.5 1 2 Miles

SAN FRANCISCO BAY SHORELINE TRANSECT LOCATION MAP 1

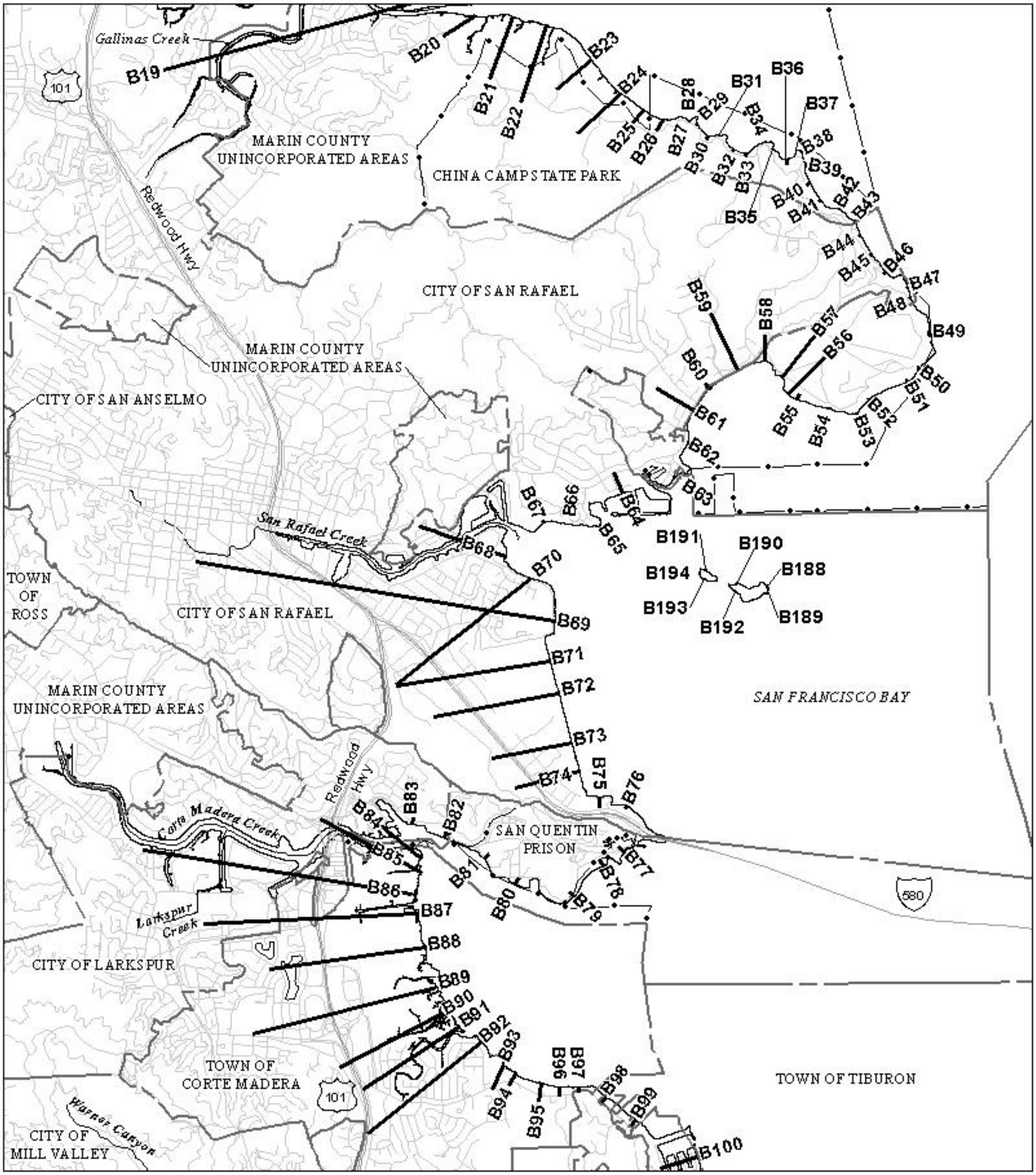

FIGURE 3

FEDERAL EMERGENCY MANAGEMENT AGENCY

MARIN COUNTY, CALIFORNIA AND INCORPORATED AREAS

SAN FRANCISCO BAY SHORELINE TRANSECT LOCATION MAP 2

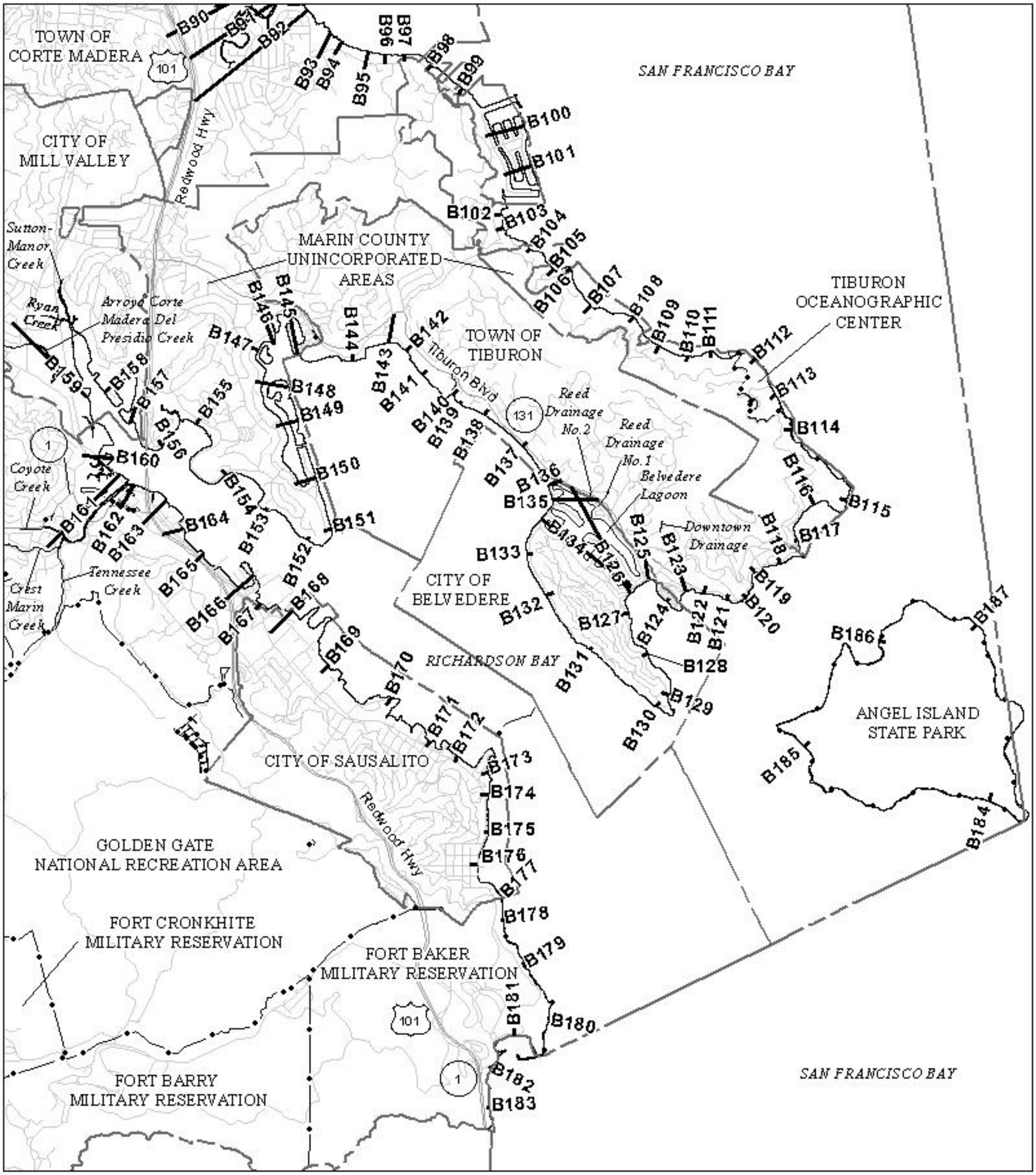

FIGURE 3

FEDERAL EMERGENCY MANAGEMENT AGENCY

MARIN COUNTY, CALIFORNIA AND INCORPORATED AREAS

SAN FRANCISCO BAY SHORELINE TRANSECT LOCATION MAP 3

3.4 VERTICAL DATUM

All FISs and FIRMs are referenced to a specific vertical datum. The vertical datum provides a starting point against which flood, ground, and structure elevations can be referenced and compared. Until recently, the standard vertical datum in use for newly created or revised FISs and FIRMs was the National Geodetic Vertical Datum of 1929 (NGVD 29). With the finalization of the North American Vertical Datum of 1988 (NAVD 88), many FIS reports and FIRMs are being prepared using NAVD 88 as the referenced vertical datum.

All flood elevations shown in this FIS report and on the FIRM are referenced to NAVD 88. Structure and ground elevations in the community must, therefore, be referenced to NAVD 88. It is important to note that adjacent communities may be referenced to NGVD 29. This may result in differences in base flood elevations across the corporate limits between the communities. The conversion factor for Marin County is +2.69 feet (100.0 feet (NGVD 29) = 102.69 feet (NAVD 88).

For more information on NAVD 88, see Converting the National Flood Insurance Program to the North American Vertical Datum of 1988, FEMA Publication FIA-20/June 1992, or contact the Vertical Network Branch, National Geodetic Survey, Coast and Geodetic Survey, National Oceanic and Atmospheric Administration, Rockville, Maryland 20910 (Internet address http://www.ngs.noaa.gov).

4.0 FLOODPLAIN MANAGEMENT APPLICATIONS

The NFIP encourages State and local governments to adopt sound floodplain management programs. To assist in this endeavor, each FIS provides 1-percent annual chance floodplain data, which may include a combination of the following: 10-, 2-, 1-, and 0.2-percent annual chance flood elevations; delineations of the 1- and 0.2-percent annual chance floodplains; and 1-percent annual chance floodway. This information is presented on the FIRM and in many components of the FIS, including Flood Profiles, Floodway Data tables, and Summary of Stillwater Elevation tables. Users should reference the data presented in the FIS as well as additional information that may be available at the local community map repository before making flood elevation and/or floodplain boundary determinations.

4.1 Floodplain Boundaries

To provide a national standard without regional discrimination, the 1-percent annual chance flood has been adopted by FEMA as the base flood for floodplain management purposes. The 0.2-percent annual chance flood is employed to indicate additional areas of flood risk in the county. For the streams studied in detail, the 1- and 0.2-percent annual chance floodplain boundaries have been delineated using the flood elevations determined at each cross section.

Revised Analyses

For this revision of the countywide FIS, new flood zones were developed and mapped for the updated San Francisco Bay coastal hazard analysis described in Section 3.3. Detailed flood hazard boundaries along the Marin County San Francisco Bay shoreline were delineated using the NOAA 2010 Northern San Francisco Bay Area LiDAR, collected February to April, 2010 (NOAA, 2010), and a 5-foot resolution DEM provided by Marin County dated 2010 (County of Marin, 2010).

Areas inundated by stillwater flooding with minimal wave hazard effects were mapped as Zone AE and the flood hazard boundary is located at the point where the ground elevation equals the stillwater elevation. In areas subject to wave runup, the flood hazard boundary is located at the point where the ground elevation equals the runup elevation, or where overtopping occurs, the boundary is located at the inland extent of overtopping. The Base Flood Elevation (BFE) in these areas is rounded to the nearest whole-foot, though the boundary is mapped using precision to the tenth of a foot. Inundation flooding is mapped inland to the point where it meets continuous high ground or encounters flooding from another flooding source. Salt marsh berms are not considered barriers to flood inundation regardless of height or continuity.

For the March 17, 2014 revision of the countywide FIS, new flood zones were developed and mapped for the detailed reaches described in Section 2.1.

Detailed floodplain boundaries along Arroyo Corte Madera del Presidio Creek, Corte Madera Creek, Corte Madera Creek Overflow, Fairfax Creek, Fairfax

Creek Overflow, Old Mill Creek, San Anselmo Creek, San Anselmo Creek Overflow, Sycamore Park Overflow, and Warner Canyon Creek were delineated using a 5-ft by 5-ft resolution DEM derived from the 2010 County of Marin digital topographic bathymetric surface model (BakerAECOM/Mill Valley, 2012). HEC-GeoRAS version 4.3.93 (BakerAECOM/Ross Valley, 2012.) was used to post-process the model data from HEC-RAS and generate draft floodplain boundaries. The draft floodplain boundaries were reviewed by an engineer and model modifications were made where appropriate. Final floodplain boundaries were derived from manual adjustment of automated floodplain output using engineering judgment, and were presented to the community for review on topographic workmaps at a scale of 1:3600, with a DEM-generated contour interval of 5 feet (BakerAECOM, 2012; Camp, 1983).

The floodplain boundaries of all, or portions of, the following streams were digitally redelineated using a DEM-generated contour interval of 2 feet, generally viewed at a scale of 1:2400 (Cartwright, 1970): Coyote Creek, Crest Marin Creek, Deer Park Creek, Greenfield Drainage, Kittle Creek, Laurel Drainage, Larkspur Creek, Old Mill Creek, Reed Creek, Ross Creek, Ryan Creek, San Rafael Creek, Sleepy Hollow Creek, Sorich Drainage, Tennessee Creek (aka Nyan Creek), and Warner Canyon Creek, as well as approximate boundaries including Lake Lagunitas and Phoenix Lake, plus other unnamed approximate and 0.2 Percent Annual Chance Zones in the vicinity of these streams.

Pre-Countywide Analysis

For each community within Marin County that had a previously printed FIS report, the scale and contour interval described in those reports have been compiled below.

Marin County (Unincorporated Areas)

Between cross sections, the boundaries were interpolated using topographic maps at a scale of 1:24,000, with a contour interval of 40 feet (U.S. Department of the Interior, 1972 et cetera).

Detailed floodplain boundaries along the Pacific Ocean and Bolinas Lagoon were delineated using topographic maps at a scale of 1:4,800, with a contour interval of 4 feet, developed from aerial photographs (Ott Water Engineers, Inc., 1983).

Approximate 1-percent annual chance floodplain boundaries in some portions of the study area were taken directly from the Flood Hazard Boundary Map for Marin County (U.S. Department of Housing and Urban Development, 1977).

Approximate 1-percent annual chance floodplain boundaries in some portions of the study area were delineated using the previously cited topographic maps (U.S. Department of the Interior, 1972 et cetera).

Some sheetflow boundaries were taken from a 1972 FIS of Marin County (U.S. Department of Housing and Urban Development, 1972).

Town of Corte Madera

For flooding in the Town of Corte Madera, the boundaries of the 1-percent annual chance flood have been delineated using topographic maps at a scale of 1:24,000 with a contour interval of 10 feet (USGS, 1954 et cetera), and field-surveyed data.

The flood boundaries delineated include areas subject to flooding from Corte Madera Creek and local tributaries, local drainage, and inflow from the bay at times of maximum high tides.

Town of Fairfax

Along Fairfax Creek, the boundaries of the 1- and 0.2-percent annual chance flood have been delineated using the flood elevations determined at each cross section; between cross sections, the boundaries were interpolated using topographic maps at scales of 1:2,400 and 1:3,600 with a contour interval of 10 feet (State of California, 1961).

San Anselmo Creek produces no flooding in the Town of Fairfax; the flows considered in this study are contained within the channel.

In Deer Park Creek and Wood Lane Drainage, the flood (sheetflow) boundaries were delineated using information supplied by local residents, available topographic information, and field-surveyed data, including cross sections.

For Bothin Creek, the estimated boundary of the 1-percent annual chance flood was determined in this study by using estimates of 1-percent annual chance discharges, culvert computations, and available topographic data augmented where necessary with field-surveyed data. Information provided by local residents was also used. Bothin Creek overflow is initiated outside the Town of Fairfax. Flow is diverted to Bothin Road, Rockridge Road, and finally Fairfax Creek. Field data obtained for flood boundary delineation indicated shallow flow.

City of Mill Valley

In the City of Mill Valley, between cross sections, the boundaries were interpolated using topographic maps at a scale of 1:24,000, enlarged to a scale of 1:6,000, with a contour interval of 40 feet (USGS, 1954 et cetera).

City of Novato

In the City of Novato, between cross sections, the boundaries were interpolated using topographic maps, and City of Novato and Watershed Area Maps, at a scale of 1:1,200 and 1:3,600, with a contour interval of 5 feet (Marin County, 1963). Subdivision maps were also used, as available.

Abnormal situations in which the 1-percent annual chance flood and/or the 0.2-percent annual chance flood are bordered by sheetflow caused by the flooding from an upstream source are the Arroyo San Jose vicinity of stream distances approximately 14,000 feet and approximately 16,000 feet above the mouth and Ignacio Creek at stream distance approximately 1,000 feet above the mouth.

Town of Ross

In the Town of Ross, between cross sections, the boundaries were interpolated using topographic maps at scales of 1:480 and 1:2,400, with contour intervals of 2 feet and 10 feet, respectively (USACE, 1966; State of California, 1961).

For stream channels designated as "Zone A Contained in Channel," the 1-percent annual chance flood boundaries are based on the existing channel alignment and right-of-way.

Areas subject to sheetflow flooding were delineated using surveyed elevations and topographic maps at scales of 1:480 and 1:2,400, with contour intervals of 2 feet and 10 feet, respectively (USACE, 1966; State of California, 1961).

Town of San Anselmo

In the Town of San Anselmo, for Laurel, Greenfield, and Red Hill Drainages, the boundary of the 1-percent annual chance flood was developed using previously determined culvert capacities and topography with additional data obtained in field surveys.

City of San Rafael

In the City of San Rafael, between cross sections, the boundaries were interpolated using topographic maps at a scale of 1:600, with a contour interval of 1 foot (San Rafael Redevelopment Agency, 1977).

Some areas in the City of San Rafael are subject to sheet flow; that is, shallow overland flooding generally less than 3 feet deep and characterized by unpredictable flow paths. The water-surface elevations of flooding in these areas are essentially independent of those along the adjacent streamway and are affected principally by obstructions in the flooded area.

Town of Tiburon

In the Town of Tiburon, between cross sections, the boundaries were interpolated using the following maps supplied by the city engineer:

1. Planimetric map of the Town of Tiburon (1973); scale: 1 inch = 300 feet.
2. Topographic map of a portion of the Town of Tiburon; scale: 1 inch = 300 feet.
3. Topographic map of State Route 131 (Tiburon Boulevard, State of California, Division of Highways); scale: 1 inch = 50 feet.

The 1- and 0.2-percent annual chance floodplain boundaries are shown on the FIRM (Exhibit 2). On this map, the 1-percent annual chance floodplain boundary corresponds to the boundary of the areas of special flood hazards (Zones A and

AE), and the 0.2-percent annual chance floodplain boundary corresponds to the boundary of areas of moderate flood hazards. In cases where the 1- and 0.2-percent annual chance floodplain boundaries are close together, only the 1-percent annual chance floodplain boundary has been shown. Small areas within the floodplain boundaries may lie above the flood elevations but cannot be shown due to limitations of the map scale and/or lack of detailed topographic data.

For the streams studied by approximate methods, only the 1-percent annual chance floodplain boundary is shown on the FIRM (Exhibit 2).

4.2 Floodways

Encroachment on floodplains, such as structures and fill, reduces flood-carrying capacity, increases flood heights and velocities, and increases flood hazards in areas beyond the encroachment itself. One aspect of floodplain management involves balancing the economic gain from floodplain development against the resulting increase in flood hazard. For purposes of the NFIP, a floodway is used as a tool to assist local communities in this aspect of floodplain management. Under this concept, the area of the 1-percent annual chance floodplain is divided into a floodway and a floodway fringe. The floodway is the channel of a stream, plus any adjacent floodplain areas, that must be kept free of encroachment so that the 1-percent annual chance flood can be carried without substantial increases in flood heights. Minimum federal standards limit such increases to 1.0 foot, provided that hazardous velocities are not produced. The floodways in this FIS are presented to local agencies as minimum standards that can be adopted directly or that can be used as a basis for additional floodway studies.

The Tennessee Creek floodway deviates from the natural channel downstream of Tennessee Valley Road. The floodflow is much greater than channel capacity, causing the majority of flow to be outside the channel adjacent to Tennessee Valley Road. It is in this area of maximum conveyance that the floodway is shown.

Floodways were defined in the Mill Valley and Ross Valley along Corte Madera Creek Overflow, Fairfax Creek Overflow, and Sycamore Park Overflow because floodflows are so much greater than channel capacity along the main streams reaches. Under current conditions, removing the conveyance capacity of these overflow reaches would cause an increase in 1-percent annual chance flood levels greater than the maximum allowable value of 1.0 foot at multiple locations along Arroyo Corte Madera del Presidio Creek, Corte Madera Creek, Fairfax Creek, Old Mill Creek, San Anselmo Creek, and Warner Canyon Creek. Floodway limits were developed utilizing equal conveyance methods and were then refined based on review comments provided by staff from Marin County Flood Control and Water Conservation District, Town of Corte Madera, Town of Ross, Town of Fairfax, Town of San Anselmo, and the City of Mill Valley. Encroachment into areas subject to inundation by floodwaters having hazardous velocities aggravates the risk of flood damage, and heightens potential flood hazards by further increasing velocities. A listing of stream velocities at selected cross sections is provided in Table 11, "Floodway Data." In order to reduce the risk of property damage in areas where the stream velocities are high, the community may wish to restrict development in areas outside the floodway.

No floodway is shown on Sutton-Manor Creek because the flooding is contained primarily within the channel with only slight shallow flooding overtopping banks.

The Eskoot Creek floodway is divided into an upstream length and a downstream length by a shallow flooding area. No floodway was computed for this shallow flooding area because of the influence of shallow tidal flooding.

Novato Creek floodflows are of the sheetflow type not conducive to the application of floodways. The sheetflow does not return to the channel; rather, it flows into Warner Creek, which is not studied inside the City of Novato corporate limits, and follows along the channel as sheetflow. From Warner Creek to San Pablo Bay, floodflows generally are a series of diked or cutoff ponding areas that fill up and spill over into adjacent ponding or diked areas.

Miller Creek floodflows upstream of U.S. Highway 101 are contained within the channel. Downstream of U.S. Highway 101, upstream of the Southern Pacific Railroad, ponding occurs; and, downstream of the Southern Pacific Railroad, estuary flooding occurs. For these areas, no floodway is shown.

Floodways are not applicable for Ross Creek since the 1-percent annual chance flow will be contained in the channel, and for Murphy Creek since the area will be inundated by sheet flow. No floodway was computed for Corte Madera Creek due to the fully developed floodplain and sheet flow potential. No floodway was computed for Kittle Creek due to the sparse development of the floodplain.

Channels in the City of San Rafael generally have no overbank areas that allow a continuous water surface across the channel and the overbanks. Overbank areas are typically lower than the channel bank elevations or high-density residential areas so that once water overtops the channel banks, it flows along a separate path as sheet flow. Floodways are not applicable in sheet flow areas.

Flood boundaries for San Francisco and Richardson Bays were delineated using the tidal elevations and tsunami wave runups determined in the hydrologic analysis, and topography was obtained by field surveys.

Flood boundaries in the vicinity of the Coloma Drainage were determined using topographic maps at a scale of 1:24,000, with contour intervals of 40 feet and 25 feet (U.S. Department of the Interior, 1954; U.S. Department of the Interior, 1956). Flooding in the Town of Tiburon may be considered to be of these three types:

1. Inundation of shoreline areas along Richardson Bay in the vicinity of the Trestle Glen drainage outfall resulting from high tides.

2. Inundation of contiguous areas as a result of overflow or pondage which occurs when estimated flood discharges exceed the capacity of road culverts and conduits under residential developments. Drainage areas northwest of Lyford Drive (Reed drainages) generally fall into this category.

3. Inundation of areas as a direct result of ponding in low areas along Tiburon Boulevard (Tiburon Drainage) or as a result of estimated flood discharges exceeding the combined capacity of a natural ponding area and pumping facility (Tiburon Downtown Drainage). Excess floodwaters follow unpredictable routes (sheet flow) in moving through the Town of Tiburon business area to Belvedere Lagoon.

With tidal flooding, seawalls or levees, in conjunction with tidal gates and/or pumps, are examples of recognized solutions. The second type of flooding comes about because of drainages being restricted for residential development. The conventional FIA floodway would maintain limitations in capacity and raise water levels another foot in areas that have been developed. A more practical solution is to provide a larger drainageway where these conditions exist, a solution that is now being used in one area and proposed in other areas of the city. The third type of flooding occurs in an area of very slight gradients at or near sea level where the available outfall cannot handle extreme flood flows. A more adequate drainageway and outlet to the bay, along with increased pump capacity and/or flood storage, may be a more practical solution.

Because of the above circumstances, development of floodways for the Town of Tiburon is not practical and none were computed.

Within the City of Belvedere there is only one basic type of watercourse flooding. That flooding is created by the larger, less frequent, floods exceeding the capacity of underground drainage facilities (within and outside the city) and by the excess waters flowing independently to Belvedere Lagoon. Because of the short overflow reaches involved and the fact that residential structures are in the overflow path, no floodway was computed.

The floodways presented in this FIS were computed for certain stream segments on the basis of equal conveyance reduction from each side of the floodplain.

Floodway widths were computed at cross sections. Between cross sections, the floodway boundaries were interpolated. The results of the floodway computations are tabulated for selected cross sections (Table 9). The computed floodways are shown on the FIRM (Exhibit 2). In cases where the floodway and 1-percent annual chance floodplain boundaries are either close together or collinear, only the floodway boundary is shown.

Encroachment into areas subject to inundation by floodwaters having hazardous velocities aggravates the risk of flood damage, and heightens potential flood hazards by further increasing velocities. A listing of stream velocities at selected cross sections is provided in Table 11, "Floodway Data." In order to reduce the risk of property damage in areas where the stream velocities are high, the community may wish to restrict development in areas outside the floodway.

The area between the floodway and 1-percent annual chance floodplain boundaries is termed the floodway fringe. The floodway fringe encompasses the portion of the floodplain that could be completely obstructed without increasing the water-surface elevation of the 1-percent annual chance flood by more than 1.0 foot at any point. Typical relationships between the floodway and the floodway fringe and their significance to floodplain development are shown in Figure 4.

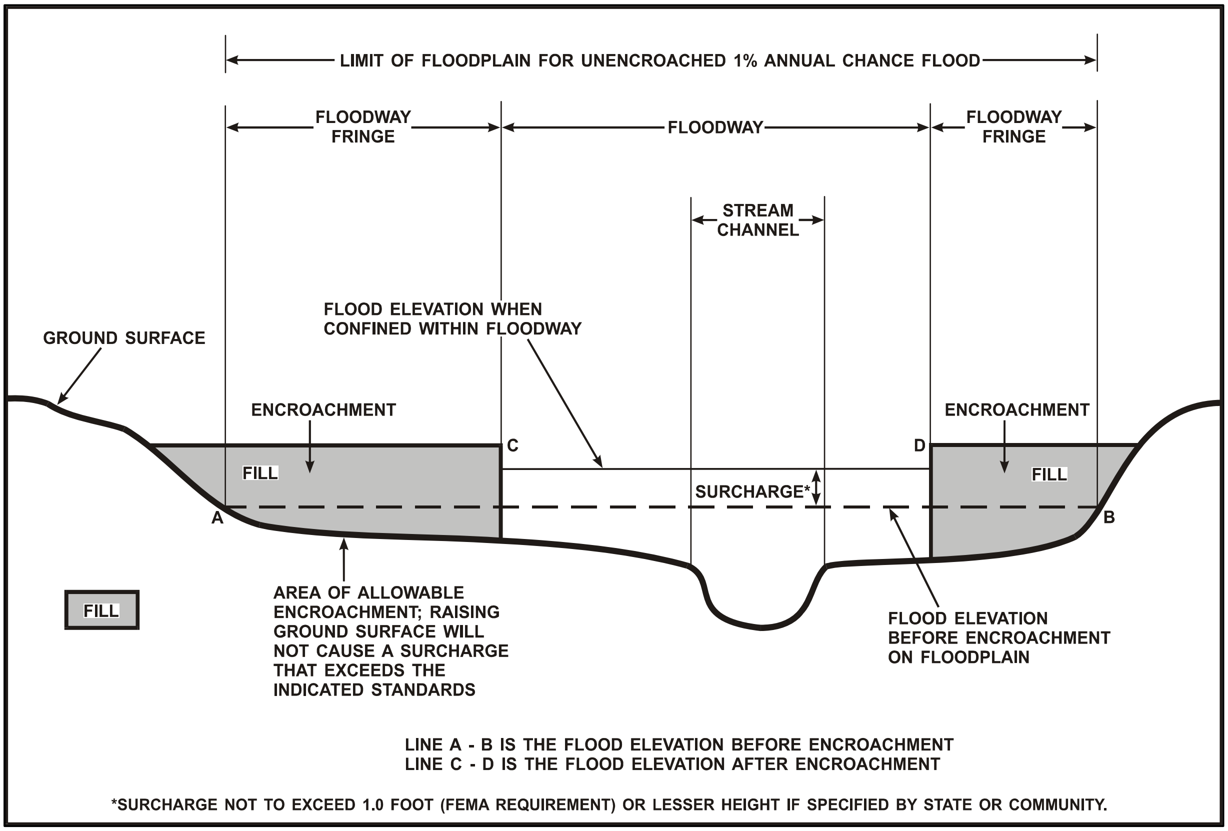

Figure 4 – Floodway Schematic

5.0 INSURANCE APPLICATIONS

For flood insurance rating purposes, flood insurance zone designations are assigned to a community based on the results of the engineering analyses. The zones are as follows:

Zone A

Zone A is the flood insurance rate zone that corresponds to the 1-percent annual chance floodplains that are determined in the FIS by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no base flood elevations or depths are shown within this zone.

Zone AE

Zone AE is the flood insurance rate zone that corresponds to the 1-percent annual chance floodplains that are determined in the FIS by detailed methods. In most instances, whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AH

Zone AH is the flood insurance rate zone that corresponds to the areas of 1-percent annual chance shallow flooding (usually areas of ponding) where average depths are between 1 and 3 feet. Whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AO

Zone AO is the flood insurance rate zone that corresponds to the areas of 1-percent annual chance shallow flooding (usually sheet flow on sloping terrain) where average depths are between 1 and 3 feet. Average whole-foot depths derived from the detailed hydraulic analyses are shown within this zone.

Zone AR

Area of special flood hazard formerly protected from the 1-percent annual chance flood event by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1-percent annual chance or greater flood event.

Zone A99

Zone A99 is the flood insurance rate zone that corresponds to areas of the 1-percent annual chance floodplain that will be protected by a Federal flood protection system where construction has reached specified statutory milestones. No base flood elevations or depths are shown within this zone.

Zone V

Zone V is the flood insurance rate zone that corresponds to the 1-percent annual chance coastal floodplains that have additional hazards associated with storm waves. Because approximate hydraulic analyses are performed for such areas, no base flood elevations are shown within this zone.

Zone VE

Zone VE is the flood insurance rate zone that corresponds to the 1-percent annual chance coastal floodplains that have additional hazards associated with storm waves. Whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone X

Zone X is the flood insurance rate zone that corresponds to areas outside the 0.2-percent annual chance floodplain, areas within the 0.2-percent annual chance floodplain, and to areas of 1-percent annual chance flooding where average depths are less than 1 foot, areas of 1-percent annual chance flooding where the contributing drainage area is less than 1 square mile, and areas protected from the 1-percent annual chance flood by levees. No base flood elevations or depths are shown within this zone.

Zone D

Zone D is the flood insurance rate zone that corresponds to unstudied areas where flood hazards are undetermined, but possible.

6.0 FLOOD INSURANCE RATE MAP

The FIRM is designed for flood insurance and floodplain management applications.

For flood insurance applications, the map designates flood insurance rate zones as described in Section 5.0 and, in the 1-percent annual chance floodplains that were studied by detailed methods, shows selected whole-foot base flood elevations or average depths. Insurance agents use the zones and base flood elevations in conjunction with information on structures and their contents to assign premium rates for flood insurance policies.

For floodplain management applications, the map shows by tints, screens, and symbols, the 1- and 0.2-percent annual chance floodplains. Floodways and the locations of selected cross sections used in the hydraulic analyses and floodway computations are shown where applicable.

The current FIRM presents flooding information for the entire geographic area of Marin County. Previously, separate Flood Hazard Boundary Maps and/or FIRMs were prepared for each identified flood-prone incorporated community and the unincorporated areas of the county. This countywide FIRM also includes flood hazard information that was presented separately on Flood Boundary and Floodway Maps (FBFMs), where applicable. Historical data relating to the maps prepared for each community, up to and including this countywide FIS, are presented in Table 12, "Community Map History."

7.0 OTHER STUDIES

An FHBM for the unincorporated areas of Marin County, California, was published in 1977 (U.S. Department of Housing and Urban Development, 1977). This study is more detailed and thus supersedes the FHBM.

An FIS was completed for the unincorporated areas of Marin County in 1972 (U.S. Department of Housing and Urban Development, 1972). That study was consulted for this study and is superseded by the results of this FIS.

FISs have also been published for the Cities of Mill Valley (U.S. Department of Housing and Urban Development, 1978), Novato (FEMA, 1984), the Towns of Fairfax (U.S. Department of Housing and Urban Development, 1977) and Corte Madera (U.S. Department of Housing and Urban Development, 1977), the City of Larkspur (FEMA, 1983), the Town of Ross (FEMA, 1980), the Towns of San Anselmo (U.S. Department of Housing and Urban Development, 1977), Sausalito (FEMA, 1980), Tiburon (U.S. Department of Housing and Urban Development, 1976), and San Rafael (FEMA, 1983), and the unincorporated areas of Sonoma County (FEMA, 1981). A FIS had been prepared for the City of Belvedere (U.S. Department of Housing and Urban Development, 1977); however, the FIS was never published.

In 1969, the USACE performed a study to investigate possible flood protection measures on Arroyo Corte Madera del Presidio Creek (USACE, 1969).

The FIA published an FHBM for the City of Novato (FIA, 1974). That map was superseded by the original FIS for the City of Novato (U.S. Department of Housing and Urban Development, 1978).

In 2010, the USACE performed a study to investigate possible flood protection measures on Corte Madera Creek in a reach generally between Sir Francis Drake Boulevard and Lagunitas Road (USACE, 2010).

In 2011, Stetson Engineers Inc. produced a Capital Improvement Plan Study for the Marin County Flood Control and Water Conservation District, Flood Zone 9 (Ross Valley). The study uses the Ross Valley flood of December 31, 2005 as its “design flood” for comparison of alternatives towards the primary goal of “substantially reducing the frequency and severity of flooding in the Ross Valley.”

Information pertaining to revised and unrevised flood hazards for each jurisdiction within Marin County has been compiled into this FIS. Therefore, this FIS supersedes all previously printed FIS Reports, FHBMs, FBFMs, and FIRMs for all of the incorporated and unincorporated jurisdictions within Marin County.

COMMUNITY NAME	INITIAL IDENTIFICATION	FLOOD HAZARD BOUNDARY MAP REVISIONS DATE	FIRM EFFECTIVE DATE	FIRM REVISIONS DATE
Belvedere, City of	June 7, 1974	None	May 2, 1977	December 16, 2008 May 4, 2009 July , 2014
Corte Madera, Town of	June 28, 1974	None	December 15, 1977	December 16, 2008 May 4, 2009 March 17, 2014 July, 2014
Fairfax, Town of	January 5, 1978	None	January 5, 1978	December 16, 2008 May 4, 2009 March 17, 2014
Larkspur, City of	July 31, 1971	May 13, 1977	March 15, 1984	December 16, 2008 May 4, 2009 March 17, 2014 July, 2014
Marin County (Unincorporated Areas)	February 25, 1977	None	March 1, 1982	November 19, 1986 May 5, 1997 May 4, 2009 March 17, 2014 July, 2014
Mill Valley, City of	June 7, 1974	None	January 3, 1979	December 16, 2008 May 4, 2009 March 17, 2014 July, 2014

TABLE 12

FEDERAL EMERGENCY MANAGEMENT AGENCY

MARIN COUNTY, CA AND INCORPORATED AREAS

COMMUNITY MAP HISTORY

COMMUNITY NAME	INITIAL IDENTIFICATION	FLOOD HAZARD BOUNDARY MAP REVISIONS DATE	FIRM EFFECTIVE DATE	FIRM REVISIONS DATE
Novato, City of	June 28, 1974	None	January 19, 1978	April 3, 1984 September 29, 1989 May 4, 2009 July, 2014
Ross, Town of	March 29, 1974	February 6, 1976	February 4, 1981	December 16, 2008 May 4, 2009 March 17, 2014 July, 2014
San Anselmo, Town of	March 1, 1974	None	December 1, 1977	December 16, 2008 May 4, 2009 March 17, 2014 July, 2014
San Rafael, City of	July 31, 1971	June 28, 1974 September 17, 1976	May 1, 1984	January 3, 1997 May 4, 2009 March 17, 2014 July, 2014
Sausalito, City of	May 17, 1974	October 3, 1975 December 19, 1978	September 30, 1980	December 16, 2008 May 4, 2009 July, 2014
Tiburon, Town of	June 7, 1974	None	May 16, 1977	December 16, 2008 May 4, 2009 July, 2014

TABLE 12

FEDERAL EMERGENCY MANAGEMENT AGENCY

MARIN COUNTY, CA AND INCORPORATED AREAS

COMMUNITY MAP HISTORY

8.0 LOCATION OF DATA

Information concerning the pertinent data used in the preparation of this FIS can be obtained by contacting FEMA, Federal Insurance and Mitigation Division, 111 Broadway, Suite 1200, Oakland, California 94607-4052.

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10.0 REVISION DESCRIPTIONS

This section has been added to provide information regarding significant revisions made since the original FIS was printed. Future revisions may be made that do not result in the republishing of the FIS report. To assure that the user is aware of all revisions, it is advisable to contact the appropriate community repository of flood-hazard data located at:

- City of Belevedere
  Planning and Building Department
  450 San Rafael Avenue
  Belevedere, California 94920

- Town of Corte Madera
  Public Works Department
  300 Tamalpais Drive
  Corte Madera, California 94976

- Town of Fairfax
  Department of Planning and Building Services
  142 Bolinas Road
  Fairfax, California 94930

- City of Larkspur
  Planning Department
  400 Magnolia Avenue
  Larkspur, California 94939

- Marin County (Unincorporated Areas)
  Department of Public Works
  3501 Civic Center Drive Rm #304
  San Rafael, California 94913

- City of Mill Valley
  Public Works Department
  26 Corte Madera Avenue
  Mill Valley, California 94941

- City of Novato
  Public Works Department
  922 Machin Avenue
  Novato, California 94945

- Town of Ross
  Public Works Department
  33 Sir Francis Drake Boulevard
  Ross, CA 94957

- Town of San Anselmo
  Public Works Department
  525 San Anselmo Avenue
  San Anselmo, California 94960

- City of San Rafael
  Public Works Department
  111 Morphew Street
  San Rafael, California 94901

- City of Sausalito
  Planning Department
  420 Litho Street
  Sausalito, California 94965

- Town of Tiburon
  Planning Department
  1505 Tiburon Boulevard
  Tiburon, California 94920

10.1 First Revision (March 17, 2014)

This study was revised on March 17, 2014, to incorporate a Physical Map Revision (PMR) for the updated hydrologic and hydraulic analysis of the Mill Valley and Ross Valley restudy. The restudied streams included all or portions of Arroyo Corte Madera del Presidio Creek, Corte Madera Creek, Corte Madera Creek Overflow, Fairfax Creek, Fairfax Creek Overflow, Old Mill Creek, San Anselmo Creek, San Anselmo Creek Overflow, Sycamore Park Overflow, and Warner Canyon Creek.

The hydrologic and hydraulic analyses for this study were performed by BakerAECOM for the Federal Emergency Management Agency (FEMA) under contract number HSFEHQ-09-D-0368, task order number HSFE09-09-J-0001. This study was completed in August 2012.

Details of the March 17, 2014 revision are incorporated within the appropriate sections and tables of this FIS.

10.2 Second Revision (<date>)

The <date> revision was initiated as a Physical Map Revision (PMR) submitted to FEMA by BakerAECOM for FEMA under Standard Ops Task Order HSFE09-10-J-0002 for Contract No. HSFEHQ-09-D-0368.

This revision involved updating the coastal mapping along the San Francisco Bay shoreline for Marin County. The PMR study area impacts the following 42 printed PMR panels: 0153, 0154, 0161, 0162, 0164, 0166, 0168, 0169, 0277, 0281, 0282, 0283, 0284, 0292, 0293, 0294, 0301, 0303, 0311, 0313, 0314, 0456, 0457, 0458, 0459, 0466, 0467, 0468, 0469, 0476, 0477, 0478, 0479, 0486, 0488, 0489, 0507, 0526, 0527, 0528, and 0531.

Detailed flood hazard boundaries were delineated using the National Oceanic and Atmospheric Administration (NOAA) 2010 Northern San Francisco Bay Area LiDAR, collected in February to April, 2010 (NOAA, 2010). For the study portion south of the I-580/Richmond-San Rafael Bridge, bathymetric information was derived from USACE dredging surveys and NOAA/National Ocean Service (NOS) Geophysical Data System (GEODAS) bathymetric data. In areas where the two datasets overlapped, the USACE data was given priority. For the study portion north of the I-580/Richmond-San Rafael Bridge, bathymetric datasets originally collected by NOAA and used in the 2011 DHI model (DHI, 2011) were merged with the topography to develop a bathymetric TIN for elevations less than 0 ft NAVD88. Elevations were linearly interpolated between the bathymetric and topographic TINs.

Several streams are independent of the San Francisco Bay, yet flow into its waters. These streams were not studied as part of this PMR, but are contained by PMR FIRM panels. These streams were reviewed for consistency with the 5-foot resolution DEM dated 2010 provided by Marin County (County of Marin, 2010). Portions of or all of the following streams were redelineated: Coyote Creek, Crest Marin Creek, Kittle Creek, Larkspur Creek, Reed Creek, Ryan Creek, San Rafael Creek, and Tennessee Creek, as well as unnamed Zone As and 0.2 Percent Annual Chance Zones. Note that the redelineations on panels 0458, 0459, 0466, 0467, 0468 & 0469 were incorporated from the Mill Valley & Ross Valley Riverine PMR (FEMA Case #10-09-0046S).

In addition, the lower reach of Downtown Drainage was redelineated based on the effective flood profile and the 2010 NOAA LiDAR. Elevation discrepancies between the new terrain and the effective Downtown Drainage stream profiles resulted in floodplains that could not be redelineated in the upper reaches because the new terrain elevations were higher than the effective profile elevations. For this case, the effective floodplain was retained and the area added to the “Coordinated Needs Management System (CNMS) database.”

No significant tie-in issues were encountered south of the I-580/Richmond-San Rafael Bridge. The 2010 NOAA LiDAR and the 5-Foot DEM provided by Marin County aided in tie-in adjustment of the flood hazard areas (NOAA, 2010; County of Marin, 2010). Flood Profiles and Floodway Data Tables for the following streams were adjusted to reflect the updated coastal stillwater elevations, as applicable: Arroyo Corte Madera del Presidio Creek (from PMR #10-09-0046S), Arroyo San Jose, Corte Madera Creek (from PMR #10-09-0046S), Coyote Creek, Crest Marin Creek, Gallinas Creek, Hilarita Drainage, Miller Creek, Novato Creek, Pacheco Creek, Reed Creek Drainage No. 1, Reed Creek Drainage No. 2, Rock Hill Drainage No. 1, Rock Hill Drainage No. 2, Ryan Creek, San Rafael Creek, Tennessee Creek, and Trestle Glen Drainage. The location of the transition point from backwater to headwater control on the flood profiles was used as the basis for placement of the zone break between the riverine and coastal AE zones.

The flood profiles for Belvedere Downtown Drainage and Tiburon Drainage were both found to be completely superseded by the coastal study results. Neither stream has corresponding streamline nor structure features in the effective DFIRM (however, this determination is based upon historic flood maps). Neither stream contains a floodway. Thus, these profiles have been removed from this revised Countywide FIS.

Details of this revision are incorporated within the appropriate sections and tables of this FIS.