SECTION 7: FLOODS

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Why are Floods a Threat to the City of Newport Beach?

Under the *National Flood Insurance Program*, a flood is:

a) a general and temporary condition or partial or complete inundation of normally dry land areas from:
   (1) the overflow of inland or tidal waters,
   (2) the unusual and rapid accumulation or runoff of surface waters from any source, or
   (3) mudslides (i.e., mudflows) which are caused by flooding and are akin to a river of liquid and flowing mud on the surfaces of normally dry land areas, or

b) the collapse or subsidence of land along the shore of a lake or other body of water as a result of erosion or undermining caused by waves or currents of water exceeding anticipated cyclical levels or suddenly caused by an unusually high water level in a natural body of water, accompanied by a severe storm, or by an unanticipated force of nature, such as flash flood or abnormal tidal surge, or by some similarly unusual and unforeseeable event which results in flooding.

This very broad definition of flooding is used in this document to address the potential for partial or complete inundation of normally dry land areas in Newport Beach as a result of storms, catastrophic failure of reservoirs, rogue waves, and tsunamis. Mudslides are discussed in Section 9. Although not occurring suddenly, this document also discusses sea level rise as a result of global climate change, and the potential short-term and long-term effects associated with increases in sea level.

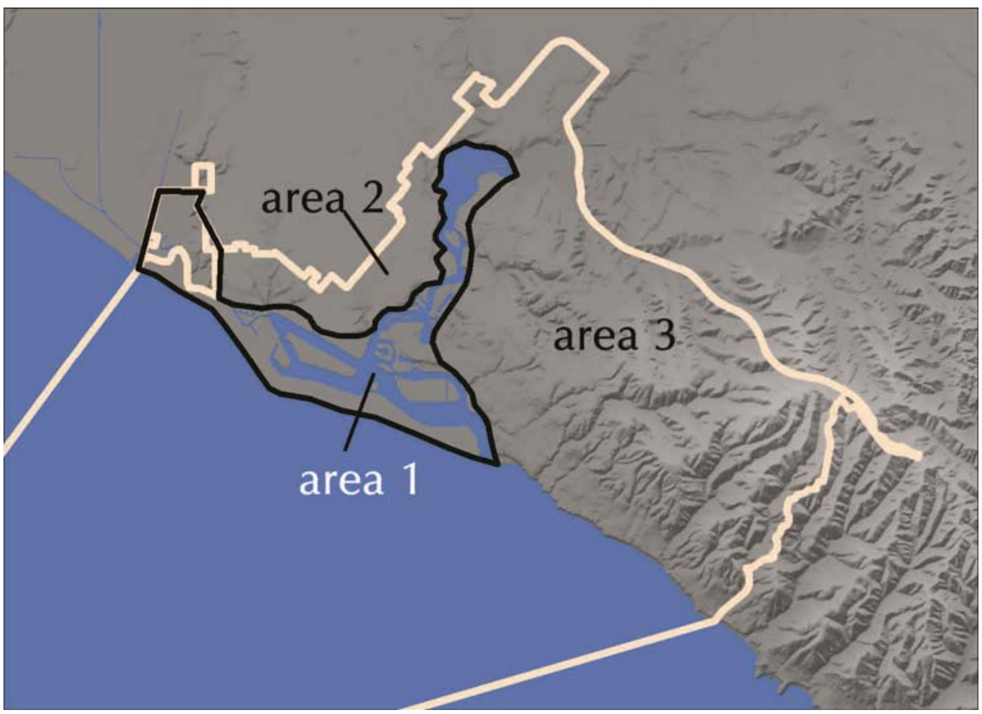
In a more specific sense, when most of us think of flooding, we think of rain, generally lots of it. In this context, floods are natural and recurring events that have traditionally been welcome: floods typically renew the landscape and increase the fertility of the floodplain soils. Floodplains also provide access to water supplies and have been used as transportation routes. For these reasons, floodplains have been alluring to populations for millennia, with many of the most important cities in history having been built adjacent to rivers. Unfortunately, these benefits come with a price – flooding is one of the most destructive natural hazards, responsible for more deaths per year than any other geologic hazard. Furthermore, average annual flood losses (in dollars) have increased steadily over the last decades as development in floodplains has increased. In short, flooding poses a threat to life and safety, and can cause severe damage to public and private property.

The City of Newport Beach and surrounding areas are, like most of Southern California, subject to unpredictable seasonal rainfall. Most years, the scant winter rains barely turn the hills green for a few weeks, but every few years the region is subjected to periods of intense and sustained precipitation that result in flooding. Flood events that occurred in 1969, 1978, 1980, 1983, 1992, 1995, 1998, 2005, and 2011 have caused an increased awareness of the potential for public and private losses as a result of this hazard, particularly in highly urbanized parts of floodplains and alluvial fans. As the population in Southern California increases, there is an increased pressure to build on flood-prone areas, and upstream of already developed areas. Increased development results in an increase in impervious surfaces, such as concrete, asphalt, and roofs. Water that used to be absorbed into the ground becomes runoff downstream. If the storm drain systems are not designed or improved to convey these increased flows, areas that may have not flooded in the past may be subject to flooding in the future. This is especially true for developments at the base of the mountains and hillsides, and downstream from canyons that have the potential to convey mudflows. Flooding hazards are a heightened concern in and downslope (and downstream) from areas burned by a wildfire.

The City of Newport Beach can be divided into three geographic areas: 1) a low elevation area comprised of West Newport, Balboa Peninsula, and Newport Bay, 2) elevated marine terraces that include Newport Mesa, Newport Heights and Westcliff, and 3) high relief terrain of the San Joaquin Hills in the eastern portion of the City (these geographic areas are shown on Map 7-1). The low elevation and terrace areas are generally drained by urbanized and relatively low relief streams that empty into Newport Bay. In contrast, rugged natural streams with steeper gradients drain the Newport Ridge and Newport Coast areas.

San Diego Creek is the main tributary to Newport Bay (see Map 7-2). Its headwaters lie about a mile east of the I-5 — I-405 intersection, at an elevation of about 500 feet. The creek flows westerly from its headwaters and empties into Newport Bay one mile west of the campus of the University of California at Irvine. Portions of San Diego Creek were channelized in 1968 for flood protection purposes.

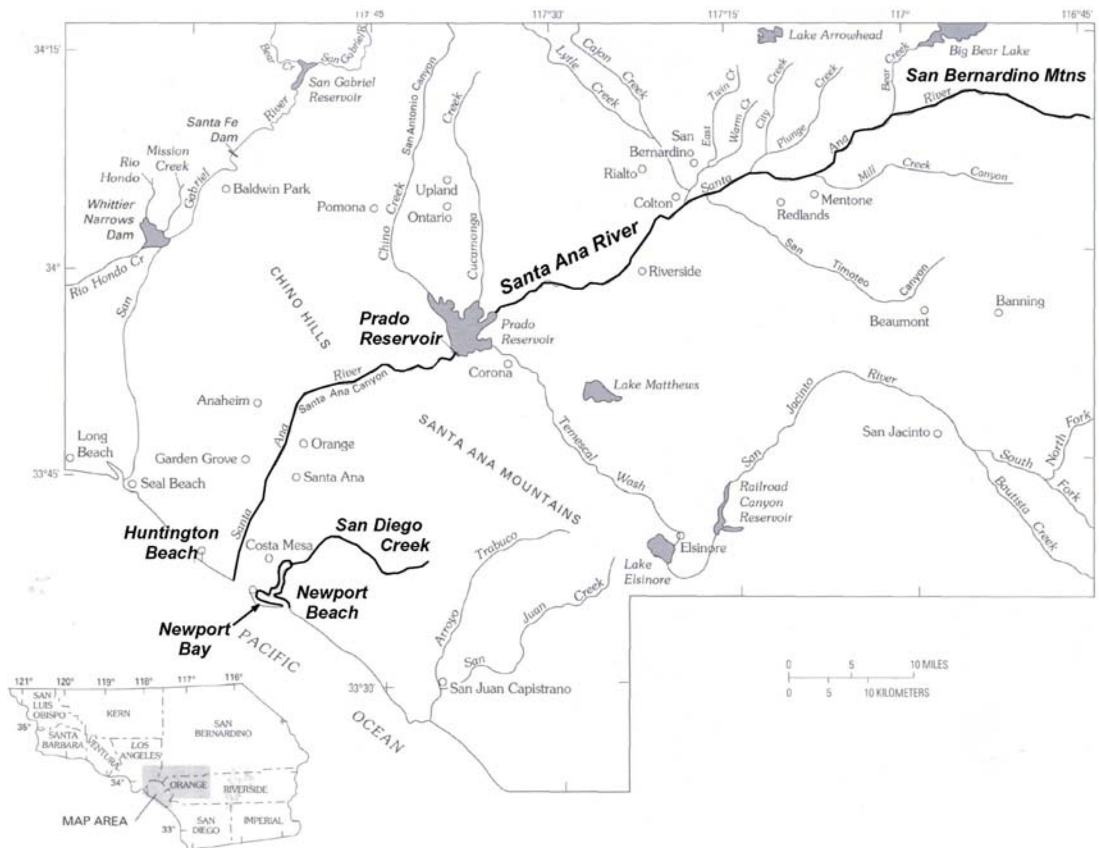
Map 7-1: Shaded Relief Map Showing General Drainage Areas Within the City of Newport Beach



The largest coastal river in Southern California, the Santa Ana River, empties into the Pacific Ocean near West Newport and forms the boundary between the cities of Huntington Beach and Newport Beach. It originates high in the San Bernardino Mountains and drains an area of about 2,470 square miles (Chin et al., 1991). Near the town of Corona, the Santa Ana River flows into Prado Reservoir (Map 7-2). Below Prado Dam, the river flows through Santa Ana Canyon, past highly urbanized cities in Orange County, and empties into the Pacific Ocean. Presently, 16.6 miles of the Santa Ana River, from its mouth to the city of Orange, are channelized for flood protection purposes. Prior to the extensive urbanization of Orange County (in the 1950s), the Santa Ana River was actively building a large alluvial fan with its apex located at the mouth of Santa Ana Canyon around the city of Anaheim. However, channelization of the river has limited any further alluvial deposition as the modern river deposits are now confined to a narrow corridor.

In addition to the Santa Ana River and San Diego Creek, the streams draining the San Joaquin Hills can also cause flooding potentially damaging to the City of Newport Beach. For example, flood hazards identified in Bonita Canyon, Big Canyon, Buck Gully, and Morning Canyon may impact residential development along these streams (these streams are shown on Plate H-7). Furthermore, a flood potential exists on smaller streams such as those draining Los Trancos Canyon and Muddy Canyon, albeit at a more localized scale. Flooding here is typically restricted to the narrow floodplains along the channel margins.

Map 7-2: Map Showing the Course of the Santa Ana River and Location of Newport Beach, Huntington Beach, Prado Dam, and the San Bernardino Mountains



(Figure adapted from Chin et al., 1991)

History of Flooding in the City of Newport Beach

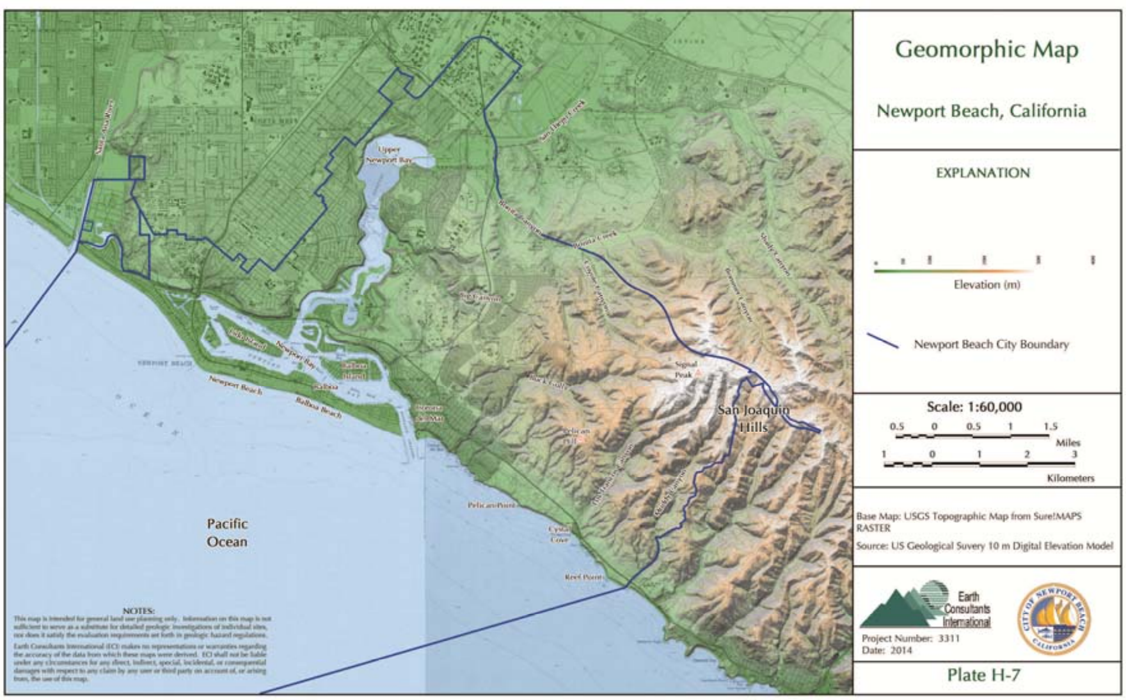
Flood hazards in the City of Newport Beach can be classified into four general categories:

1) flooding of the low-lying coastal areas as a result of intense rain, often accompanied by high tides, storm surges and strong winds;
2) localized flash flooding from small, natural channels,
3) more moderate and sustained flooding from the Santa Ana River and San Diego Creek; and
4) low probability but high-impact flooding caused by tsunamis, rogue waves, and other coastal processes.

Storm-related floods and flash floods are often of short duration, but have high peak volumes and high velocities. This type of flooding occurs in response to the local geology and geography, and the built environment (human-made structures). The San Joaquin Hills in the eastern part of the City consist of sedimentary rock types that are fairly impervious to water so little precipitation infiltrates the ground; rainwater instead flows along the surface as runoff. When a major storm moves in, water collects rapidly and runs off quickly, making a steep, rapid descent from the hills into man-made and natural channels in the built environment and onto the marine terraces along the coast.

The major streams emanating from the San Joaquin Hills (Big Canyon, Coyote Canyon, Bonita Canyon, Buck Gully, Morning Canyon, Los Trancos Canyon, and Muddy Canyon) do not have stream gauges (Map 7-3 and Plate H-7). Therefore, peak discharge data are not available for these drainages. Additionally, the areas around these canyons became populated only relatively recently and there have been no significant storms in the past few years in this area, so historic accounts of flooding are unavailable. However, flooding on these streams likely occurs during major floods. For example, a flash flood in 1941 caused up to 6 feet of downcutting and undermined foundations in Laguna Canyon, approximately 3 miles southeast of Newport Beach. Although Laguna Canyon has a larger drainage area, channels in eastern Newport Beach probably experienced similar flooding in 1941, since both basins have similar characteristics and the storm intensity was comparable in both areas given their proximity.

Map 7-3: Geomorphic Map of Newport Beach Showing the Canyons Draining the San Joaquin Hills and the Low-Lying Areas in the City
(for a larger version of this map, refer to Plate H-7 in Appendix H)



Flooding on **San Diego Creek** has historically caused significant damage in Newport Beach because it is the biggest stream, with a drainage area of 118 square miles, to flow through the City (Map 7-4). Channelization of San Diego Creek also resulted in increased sediment flow into Upper Newport Bay, requiring extensive dredging projects to restore the ecosystem. The U.S. Geological Survey used to maintain three stream gauges along San Diego Creek. One of these, gauge No.

11048500 on Culver Drive, was operated continuously from 10/01/1949 to 09/30/1985 (its location is shown on Figure 7-1a). These data provide a relatively long-term record of mean daily discharge and peak flows that can be used to describe the flooding history and future flooding potential of the Newport Beach area. The Campus Drive gauge (gauge No. 11048555, see Figure 7-2) on San Diego Creek, which is closer to Newport Beach, unfortunately only operated sporadically between 10/01/1977 and 09/30/1985.

Map 7-4: Location Map Showing the San Diego Creek Watershed

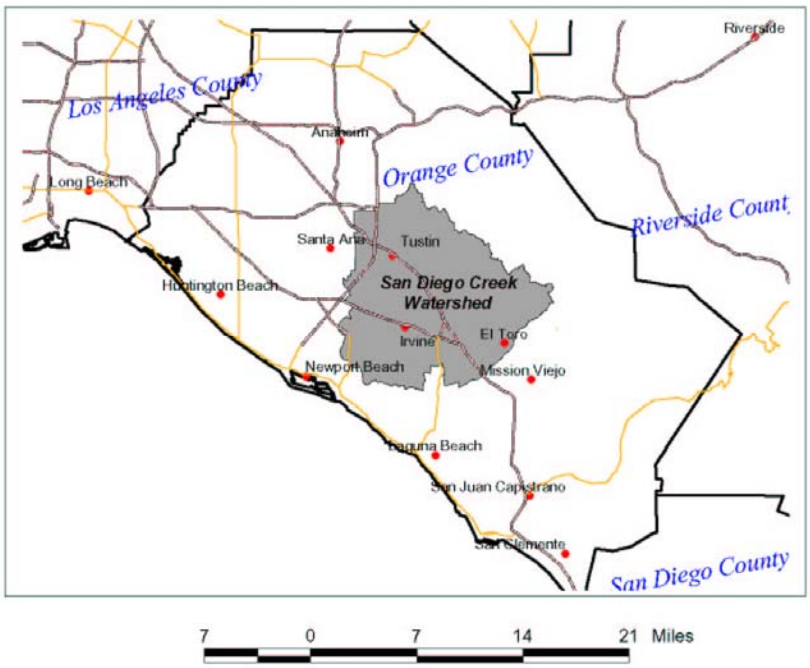
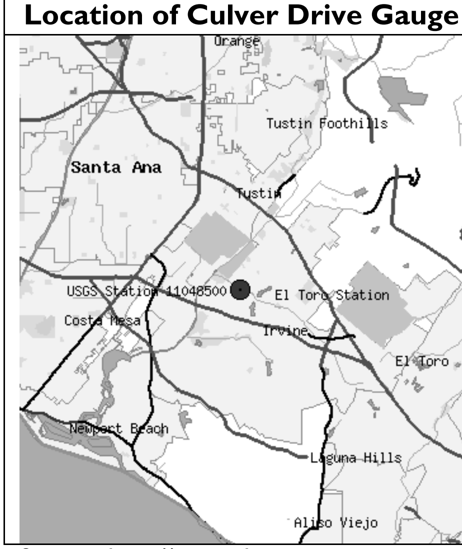
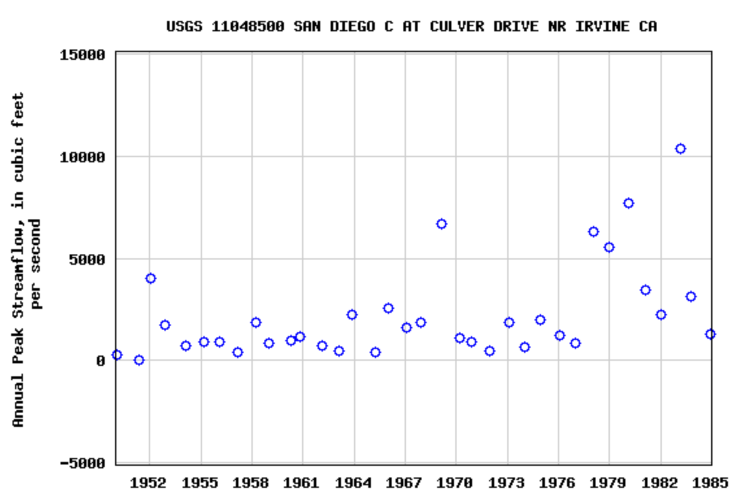
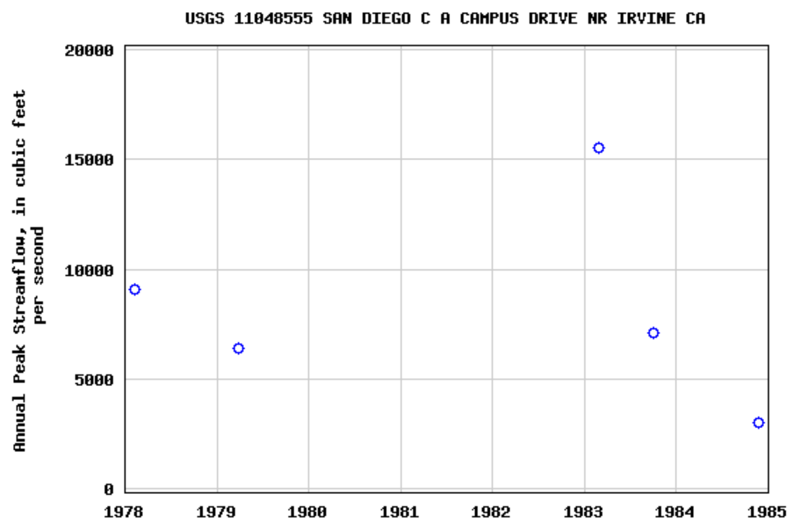


Figure 7-1a: Map Showing Location of Culver Drive Gauge	Figure 7-1b: Hydrograph Showing Peak Discharges at this Gauge (for the period 1950-1985)
	

Source: http://waterdata.usgs.gov

The largest flood measured during the 36-year period of record occurred in 1983, when the Campus Drive gauge measured a peak discharge of more than 15,000 cfs (Figure 7-2). A peak discharge of approximately 10,000 cfs was recorded 5 miles upstream at the Culver Drive gauge during the same flood event (Figure 7-1). The next highest peak flows measured in the area date from 1980 (see Figure 7-1b).

Figure 7-2a: Map Showing Location of the Campus Drive Gauge	**Figure 7-2b: Hydrograph Showing Peak Discharges at this Gauge** (for the periods 1978-1979 and 1983-1985)



Source: http://waterdata.usgs.gov

During the floods of February 24th, 1969 Orange County received more than 6 inches of rain (Orange County Register 1/13/95). The gauge on San Diego Creek at Culver Drive measured a peak flow of about 6,700 cfs (Figure 7-1b). Flooding in 1969 washed out MacArthur Boulevard when the existing storm drain at Jamboree Road was overwhelmed. High water also caused damage to Barranca Parkway near its intersection with Culver Road (Figure 7-3). Other roads and agricultural fields were also damaged by this event (Figure 7-4).

One of the largest and most intense El Niño events on record occurred during the winter of 1997-98. This was also one of the worst storm seasons reported in Southern California. Low-latitude Pacific storms, similar to those in 1938, again moved over Southern California resulting in periods of high-intensity cloudbursts on previously saturated ground. On Friday, February 6th, Newport Beach received 1.8 inches of rain over a 2-hour period, and more than 2.9 inches of rain for the day. A storm three days earlier had already saturated the ground and damaged the Balboa Pier. As a result of the second storm, the Newport Beach area experienced flooding, power outages, school evacuations, snarled traffic due to road closures, and several mudslides in the Upper Newport Bay area (between Jamboree Drive and Carnation Avenue). Serious flooding along Mariner's Mile due to water collecting along curbs and gutters led to the closure of a 2-mile stretch of Coast Highway between Dover Drive and Superior Avenue. Other areas that were flooded include 19th Street, Anaheim and Pomona Avenues, and Balboa Boulevard. Corona del Mar High School, Newport Elementary, Newport Harbor High School, and Andersen Elementary all experienced flooded classrooms (February 7, 1998 edition of the *Daily Pilot*). Damage from this storm was estimated at nearly $4.3 million. Newport Beach and Irvine suffered the most flooding damage.

Figure 7-3: Photograph Looking Upstream (northeast) at San Diego Creek at its Confluence with Barranca Parkway on February 25th, 1969

(Photograph used with permission from the Orange County Flood Control District's Library)

Figure 7-4: Photograph Looking Downstream at Flooding on Peters Canyon Wash (February 25, 1969)

(Photograph used with permission from the Orange County Flood Control District's Library)

During the storms of January 2005, several roadways, businesses and residential areas in Newport Beach were flooded when the storm surge coincided with a high tide of approximately 7 feet. It is not unusual for localized flooding of streets, businesses and residences to occur along the Balboa

Peninsula and other low-lying coastal areas of the City when storm surges, strong winds and high tides coincide (Figures 7-5a and 7-5b). No significant flooding was reported in Newport Beach between 2008 and the winter of 2012-2013, although significant flooding was reported in the Orange County area in December 2010. On December 19-22, 2010 there was heavy rain and periods of serious flooding in the region. Many areas reported flash flooding, debris flows and mudslides, and most rivers in the county reached flood stage. Damage in Orange County was estimated at $36 million, with $12 million in damages reported in Laguna Beach. The storms caused numerous traffic collisions, roadway flooding and road closures, swift water rescues, and damage to homes, businesses and infrastructure. Twelve miles of beaches in Orange County were closed due to massive amounts of debris and pollution brought about by the storm runoff (https://www.ncdc.noaa.gov/stormevents/eventdetails.jsp?id=272613).

Figures 7-5a and 7-5b: Flooding of Streets, Businesses and Residences in Newport Beach as a Result of the January 11, 2005 Storm
(Photos taken by Mr. Rick Greaney, General Services Department, City of Newport Beach.)

FEMA's records include 263 flood claims filed by residents of Newport Beach, including Balboa Island and Corona del Mar, between 1977 and 2010. The amounts paid by FEMA on these claims range from $0 to nearly $275,000.00, with an average of $6,040.00. Of the properties impacted, 12 have filed repetitive losses. As of the end of 2010, five of these properties had been mitigated. According to FEMA's records, of the remaining seven properties that have not been mitigated, only three are currently insured for flooding.

Historic Flooding in Orange County

The **Santa Ana River** is the largest drainage in Southern California. The river has flooded historically many times, and the course of the river has changed, at times significantly, in response to these flooding events. For example, the river currently outlets into the Pacific Ocean near West Newport; however, between 1769, when the Spanish first arrived in Southern California, and 1825, the Santa Ana River flowed out to sea through Alamitos Bay, near the present-day boundary between Los Angeles and Orange counties. In 1825, when severe storms caused extensive flooding in the area, the river resumed its ancient course through the Santa Ana Gap and around the toe of Newport Mesa to the ocean. Several other storms impacted the Southern California area between

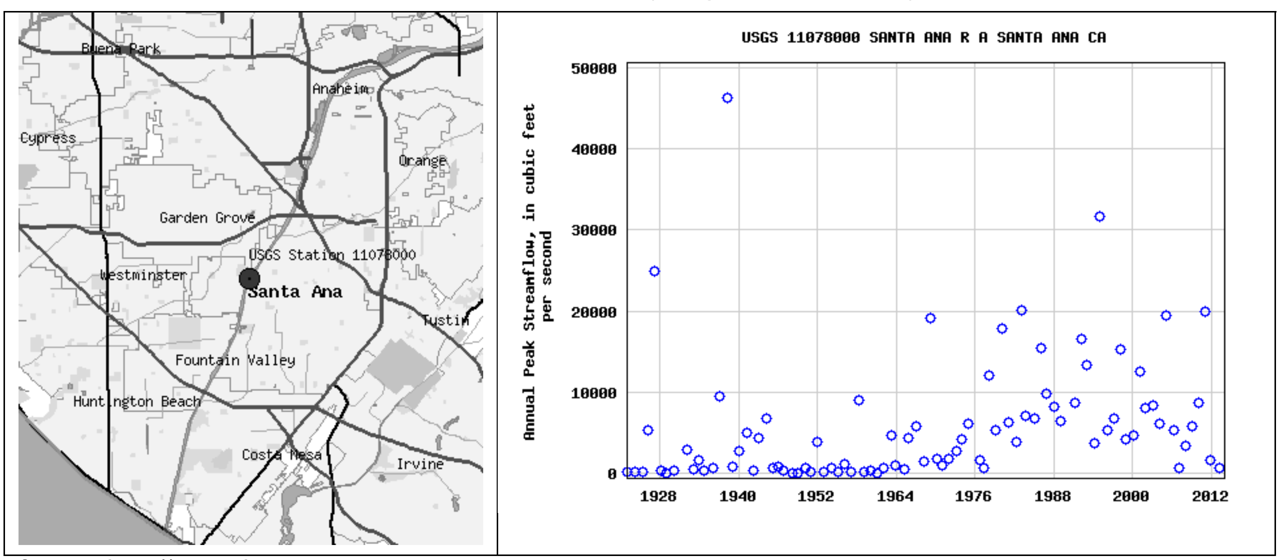
1770 and 1825 (in 1770, 1780, 1815, 1821, and 1822), but there are no records of flooding specific to the Santa Ana River.

The largest documented flood in the Santa Ana River valley occurred in the winter of 1861-1862 when it rained nearly continuously for a month. Based on an account by Crafts (1906, as reported in Troxell et al., 1942), “the fall of 1861 was sunny, dry and warm until Christmas, which proved to be a rainy day. All through the holidays there continued what we would call a nice, pleasant rain, as it often rains in this section for days at a time. This . . . lasted until the 18th of January, 1862, when there was a downpour for 24 hours or longer.” This intense downpour destroyed settlements along the Santa Ana River from San Bernardino County to present-day Santa Ana and created an inland sea, up to 4 feet deep, in coastal Orange County. The river mouth swept as far to the southeast as the rock bluffs that today form the east side of the Newport Bay channel entrance. The peak discharge as a result of this storm was estimated at 320,000 cfs (City of Huntington Beach, 1974).

In 1867-1868, the area again experienced sustained precipitation, but of less intensity than that in 1862; therefore there was less damage. Then, in 1884, there were two floods. The first storm occurred in the latter part of February, saturating the ground. The second storm, which came six to eight days later, caused extensive damage. The Santa Ana River cut a new channel to the sea starting from near its confluence with Santiago Creek, cutting through farmlands east of the old channel, and discharging into the ocean about 3 miles southeast of its previous outlet. As much as 40 inches of rain were recorded in the area for that season (Troxell et al., 1942). Floods were also reported in the Los Angeles area in 1886, 1889, 1891, and in 1909. The 1909 floods caused significant damage in the upper reaches of the Santa Ana River, in San Bernardino and Riverside counties.

Until 1919, the river’s outlet to the sea continued to migrate back and forth from the rock bluffs in Newport Bay (U.S. Corps of Engineers, 1993) to a point near the present day intersection of Beach Boulevard and Pacific Coast Highway in Huntington Beach. In 1919, a year after a local flood, local interests built a dam at Bitter Point (which appears to have been located near present-day 57th Street and Seashore Drive) to stop the flow into Newport Bay, and cut a new outlet for the Santa Ana River, where it has remained to date.

Figure 7-6: Location and Peak Discharge Hydrograph for the Santa Ana Gauge on the Santa Ana River (Gauge No. 11078000)



Source: http://waterdata.usgs.gov

The most destructive flood in Orange County occurred in 1938. Intense storms brought heavy rainfall to Orange County and Newport Harbor. In the Santa Ana River drainage, the 1938 storms caused 34 deaths (nearly 100 deaths were reported throughout California), 1,159,000 acres of flooded land, more than 2,000 people left homeless, and more than $14 million in damages (Feton, 1988; Troxell et al., 1942). Peak discharge in Santa Ana Canyon was estimated at 100,000 cfs. By the time floodwaters reached Santa Ana, the discharge had attenuated to ~46,000 cfs (Figure 7-6), which was still enough for the floodwaters to overtop the earthen levees and flood much of Huntington Beach and Newport Beach (Figure 7-7).

The damage caused by the 1938 flood reinforced the need for an upstream flood control facility. Prado Dam was constructed near Corona in 1941 to greatly reduce the flooding hazard in coastal Orange County. Operation of the dam during large rain events has effectively limited flow in the lower Santa Ana River channel. In 1969, when the second largest storm of the 20th century swept through Southern California, Prado Dam was used to manage the flow into the lower reaches of the river: During this event 77,000 cfs flowed into Prado Dam, but only 6,000 cfs were released downstream (City of Huntington Beach, 1974). When flow from downstream tributaries (e.g., Santiago Creek) was added to the dam release, discharge measured at the gauge in Santa Ana was limited to 20,000 cfs (Figure 7-6). This is a significant decrease compared to the ~46,000 cfs recorded at the same gauge during the 1938 flood.

Figure 7-7: Oblique Aerial Photograph Looking West at the Mouth of the Santa Ana River During the 1938 Flood

(Note the breaks in the levees at Verano Street and Adams Street and the inundation of West Newport and most of Huntington Beach.)

(Photograph from Troxell et al., 1942)

In January and February 1980, California and Arizona were struck by several storm systems that brought much higher than normal precipitation to these areas. Between February 12 and February 20, the Prado Dam Flood Control Reservoir filled with approximately 100 acre-feet of water; between February 17 and February 26, daily mean discharges of more than 4,400 cfs were being measured at the Santa Ana gauge. These continuous high discharges scoured that portion of the riverbed between 17th Street and Harbor Avenue to depths of up to 20 feet, and undercut segments of the concrete lining along the banks (Chin et al., 1991). Six major bridges and numerous smaller bridges were impacted by severe scour. Extensive scour of the piles supporting the Fifth Street bridge necessitated closure of this bridge for nearly a year while repairs were made (see Figure 7-8). Even higher peak discharges were recorded at the Santa Ana gauge during the winters of 1983 and 1995 (see Figure 7-6). The historic maximum release from Prado Dam, of 10,100 cfs, occurred on 13 January 2005 (http://www.spl.usace.army.mil/resreg/htdocs/prdo.html).

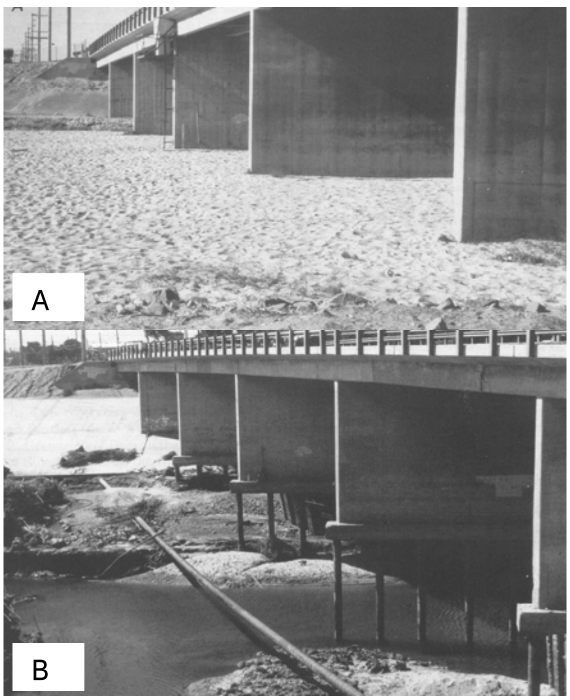


Figure 7-8: The Santa Ana River at the 5th Street Bridge in Santa Ana, showing the riverbed prior to the 1980 floods (A), and the channel after the 1980 floods (B). The channel was scoured 18 to 20 feet deep, exposing the piles supporting the bridge. The bridge was closed almost a year for repairs. (From Chin et al., 1991).

The 1997-1998 flooding discussed previously resulted in nearly $4.3million in property losses and $249 thousand in crop losses in Orange County. The $4.3 million in property losses may be significantly underestimated, given the widespread damage reported throughout the county, and given how a storm in 2010 is reported to have caused $12 million in damages in Laguna Beach alone.

Historic Flooding in Southern California

The main flooding events recorded in the Santa Ana River and San Diego Creek are described in the previous section. Given the settlement history of the area, however, to better understand the flooding patterns in Southern California, one has to look at the Los Angeles River (see Table 7-1). Records show that since 1811, the Los Angeles River has flooded more than 30 times, roughly about once every 6 years. But averages are deceiving, for the Los Angeles basin goes through periods of drought and then periods of above-average rainfall. For example, between 1868 and

1884, a period of 16 years, there were no major floods, but this was followed by a series of wet years with floods in 1885, 1886, 1889 and 1891. A similar cluster of wet years was recorded in the 1990s.

Table 7-1: Historical Floods in Los Angeles County

Year	Comments
1770-1771	Great flooding on the L.A. River recorded by Father Juan Crespi. River overflowed its channel.
1771-1772	Flooding recorded by Spanish Mission Fathers. San Gabriel Mission crops destroyed.
1775-1776	Due to heavy flooding, San Gabriel Mission was moved about 6 miles back from the river.
1779-1780	Flooding recorded by Spanish Mission Fathers. Flows filled riverbed and flooded the lowlands where wheat and barley had been planted.
1811	Flooding reported, although records are sparse.
1815	Flooding washes away the original Plaza in Los Angeles. River changes course at Alameda and 4th Street to cut west and join Ballona Creek. From there it emptied into Santa Monica Bay.
1822	A great flood on the Los Angeles River "covered all the lowlands and reached a greater height than was ever known before."
1824-25	The greatest of the earlier recorded floods. Los Angeles River changed its course back from the Ballona wetlands to San Pedro. Before this storm, the river would spread over the entire area, filling depressions at the surface and forming lakes, ponds and marshes, rarely discharging its waters into the sea. The 1825 floods cut a riverway to the ocean, draining the marshlands and causing the forests to disappear.
1832	Heavy flooding caused the drainage near Compton to change so that many lakes and ponds that "had been permanent, became dry a few years thereafter." Drainage of these ponds and lakes completed the destruction of the forests that used to cover a large part of southern L.A. County.
1849 – 1860	Floods of various magnitudes occurred in 1849-1850, 1851-1852, and 1859-1860.
1861-62	The "great flood" or the "Noachian deluge of California." Fifty inches of rain fell during December and January. The entire valley from Los Angeles to the ocean was a great lake. Part of the river split and drained into Ballona Creek. San Gabriel River also overflowed its banks and started a new channel.
1867-68	Floods spill over river channel and create a large, temporary lake out to Ballona Creek. San Gabriel River breaks out of its channel and washes thousands of acres of land.
1884	Two periods of intense rainstorms separated by 6 to 8 days. The first storms caused little damage. The second washed all but one of the bridges across the L.A. River, washed away many houses, and drowned several people. Parts of Los Angeles flooded 3 to 4 feet deep.
1886-87	A good part of Los Angeles was inundated. The levees were damaged and railway communication was impossible for 2 to 3 weeks.
1889	Flood on Christmas Day caused much damage; bridges and levees washed away; the old San Gabriel, new San Gabriel and L.A. Rivers joined near Downey and formed one body. Los Angeles River overtopped its channel.

Year	Comments
1914	Heavy flooding in January and February. Great damage to Los Angeles harbor.
1916-1938	Flooding in 1916. Minor floods causing damage in certain areas reported in 1918, 1921-1922, 1926, 1927, 1931, 1932, 1934, 1936, and 1937.
1934	Moderate to severe flooding starting January 1. Over 40 dead in La Cañada – Glendale area. Debris flow killed 12 people who had taken shelter in the Montrose Legion Hall.
1938	Series of storms beginning December 1937. March floods exceeded all previous floods for which records were available. Large tracts inundated; bridges, highways and railroads severely damaged. 87 people killed, over $78 Million (1938 dollars) in damage.
1941-1944	Los Angeles River floods five times.
1952	Moderate flooding.
1969	Recurrent precipitation during January and February nearly approached the largest total since 1884. Nearly 40 people died as direct result of the floods in Southern California, and more than 10,000 had to be evacuated.
1978	Two moderate floods.
1979	Los Angeles experiences severe flooding and mudslides.
1980	Flood tops banks of river in Long Beach. Sepulveda Basin spillway almost opened. Flooding killed 36, left 6,000 homeless, affected 100,000 and caused $350 million in damages.
1983	Flooding kills six people.
1992	15-year flood. Motorists trapped in Sepulveda basin. Six people dead.
1994-1995	Heavy flooding throughout the State. The total damages are estimated at $2 billion.
1997-98	The 1997 floods caused extensive damage in 48 California counties, including Los Angeles and Orange counties. Total damages were estimated at $1.8 billion. The 1998 El Niño storms also caused damage, but this was less than it could have been because many had taken measures to reduce their risk following the 1997 storms.
2003-2004	The rains followed the extensive fires of 2003; in many areas, canyons chocked with ashes and debris caused debris flows that did substantial damage downstream. Flash floods killed 18 in the Southern California area.
2004-05	The second-wettest year on record in the Los Angeles Basin; the rains caused extensive damage in some areas, triggering landslides and debris flows. Between Feb.17-23, flooding in Los Angeles County alone killed 9 people, affected 150, and caused $250 million in damages. In January, flooding and landsliding caused 28 deaths, 8 injuries, affected 500, and caused $200 million in damages.
2005-06	Flooding due to intense precipitation between Dec. 31 and Jan. 18 killed 3 people, affected 3,600, and caused $245 million in damages in northern and Southern California, and Nevada.
2010-2011	California winter storms caused flooding, debris flows and mudflows in several counties, including Orange County. Major Disaster Declaration issued on January 26, 2011.

Sources: http://www.em-dat.net/disasters/; htpp://www.fema.gov

What Factors Create Flood Risk?

Climate

Flooding occurs when climate, geology, and hydrology combine to create conditions where water flows outside of its usual course. As the historical record shows, in the City of Newport Beach, climate (storm-induced precipitation and storm-induced high waves), high tides, geography, and elevated sea levels can combine to create seasonal coastal flooding conditions resulting in beach erosion and property damage.

Average yearly precipitation in the Newport Beach area is about 12 inches (see Table 7-2), whereas 14 inches of precipitation fall annually in Santa Ana (Table 7-3). These tables show that areas closer to the coast receive a little less precipitation, on average, than inland areas.

Table 7-2: Average Annual Rainfall by Month for the Newport Beach Harbor Area

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Inches	2.5	2.4	1.9	1.1	0.2	0.1	0.0	0.1	0.3	0.3	1.2	2.0	**11.9**

Data based on 59 complete years between 1931 and 1995.

Table 7-3: Average Annual Rainfall by Month for the Santa Ana Area

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Inches	3.0	2.9	2.4	1.1	0.2	0.1	0.0	0.1	0.2	0.4	1.4	2.4	**14.1**

Data based on 64 complete years between 1931 and 1995.
Source: http://www.worldclimate.com/

Not only does rainfall vary from one location to the next, often within short distances, but rainfall in Southern California is extremely variable from year to year, ranging from one-third the normal amount to more than double the normal amount. "Averages" are not particularly representative of rainfall in the Southern California area, as illustrated with the following discussion about downtown Los Angeles: the average annual rainfall in Los Angeles for the last 135 years (between 1877 and 2012) is 14.98 inches, but rainfall during this time period has ranged from only 3.21 inches in 2006-2007 to 38.2 inches in 1883-1884 (www.laalmanac.com/weather/we13.htm). In fact, in only 24 of the past 135 years has the annual rainfall been within plus or minus 10 percent of the 14.98-inch average, and in only 42 years has the annual rainfall been within plus or minus 20 percent of the average value. This makes the Los Angeles basin a land of extremes in terms of annual precipitation.

Flood risk and water supply in the western United States, including Southern California, are closely tied to **atmospheric rivers** (ARs). Much research in the last decade has focused on the study of these meteorological phenomena, in great part due to the increased use of radar, satellite data, and other imaging techniques. ARs are narrow streams of water vapor transported in the lower atmosphere (Zhu and Newell, 1998) that are thought responsible for most of the very large storms on the west coast of the United States, and that account for 30 to 50 percent of the precipitation that falls in California. Typically packing high wind speeds, ARs are typically 400 to 500 kilometers wide, but are thousands of kilometers long, sometimes extending across whole ocean basins. When ARs traveling across the Pacific Ocean collide with the mountain ranges in the west coast, the vapor is forced upwards, where it condenses and rains out, leading to significant flooding (Ralph and Dettinger, 2011).

The U.S. Geological Survey's (USGS) Multi Hazards Demonstration Project (MHDP) has been combining various science disciplines to test and improve the resiliency of communities to natural disasters. By developing a disaster scenario (such as the 2008 ShakeOut Earthquake Scenario discussed in Section 6) scientists, engineers, and other experts are engaging emergency planners, first responders, businesses, universities, insurance companies, government agencies and the public in preparing for a major natural disaster. The second major project of the MHDP is a catastrophic winter storm scenario consisting of a hypothetical (but not unrealistic) Pacific storm striking the west coast of California, similar in intensity to the 1861-1862 series of storms that resulted in state-wide flooding that left the central coast impassible, the capital underwater for three months, and the State bankrupt.

The hypothetical **ARkStorm** (for Atmospheric River 1,000), if it occurred today, would overwhelm the State's flood protection system, which is normally designed to control the 100- to 200-year storm runoff. Property damage and business disruption from the ARkStorm are estimated to be on the order of $725 billion, nearly three times the loss expected for the hypothetical southern California ShakeOut earthquake (Porter et al., 2011). The USGS report indicates an ARkStorm is not only plausible, but probable, and may not be a worst case. The geological record suggests that six megastorms have occurred in California in the past 1,800 years – all more severe than the 1862 event. The products of the ARkStorm Scenario are intended to be used by emergency planners, policymakers and other to review disaster preparedness, conduct risk assessments and disaster drills, explore ways to adequately fund response and recovery, plan future hazards mapping, and educate the public.

Storms that bring precipitation to Southern California typically occur in the winter, or are associated with summer tropical storms (or monsoons). Each of these is described below.

- **Winter Rainfall:** Winter storms are characterized by heavy and sometimes prolonged precipitation over a large area, and are typically associated with atmospheric rivers. These storms usually occur between November and April and are responsible for most of the precipitation recorded in Southern California. The storms originate over the Pacific Ocean and move eastward (and inland). The mountains, such as the San Gabriel and San Bernardino Mountains, form a rain shadow, slowing down or stopping the eastward movement of this moisture. A significant portion of the moisture is dropped on the mountains as snow. If large storms are coupled with snowmelt from these highlands, large peak discharges can be expected in the main watersheds at the base of the mountains. Some of the severe winter storm seasons that have historically impacted the Southern California area have been related to El Niño events.

  El Niño is the name given to a phenomenon that starts every few years, typically in December or early January, in the southern Pacific, off the western coast of South America, but whose impacts are felt worldwide. Briefly, warmer than usual waters in the southern Pacific are statistically linked with increased rainfall in both the southeastern and southwestern United States; droughts in Australia, western Africa and Indonesia; reduced number of hurricanes in the Atlantic Ocean; and increased number of hurricanes in the Eastern Pacific. Two of the largest and most intense El Niño events on record occurred during the 1982-83 and 1997-98 water years. [A water year is the 12-month period from October 1 through September 30 of the next year. Often a water year is identified only by the calendar year in which it ends, rather than by giving the two years, as above.] These are also two of the worst storm seasons reported in Southern California.

  Some of the wetter winter storms have been attributed to a type of atmospheric river termed the "Pineapple Express," a term that has been used in California for many years. These are atmospheric rivers that draw in moisture from the tropics near Hawaii. For example, the severe storms of December 2004 and January 2005 have been blamed on a "Pineapple Express" jet stream that passed over the Hawaiian Islands and brought moisture-laden air directly from the tropics to the west coast of California. In December 2004, as this condition was developing, the northern jet stream shifted towards the California coast allowing storms from the north to tap into the deep tropical moisture brought by the sub-tropical jet stream, dramatically increasing the rainfall in southern California (NOAA, 2005a).

- **Summer Monsoons and Thunderstorms:** Another relatively regular source of heavy rainfall, particularly in the mountains and adjoining cities, is from summer tropical storms. Tropical rains or monsoons typically occur in the summer or early fall, between July and October. These storms originate as tropical cyclones in the warm waters off Baja California, in the eastern Pacific Ocean, and move northward into Southern California. By the time they move onshore over Baja California, the cyclones generally diminish to less-than-tropical-storm strength, but their remnants often bring significant precipitation to the Southern California mountains and deserts. Tropical storms that have dropped significant rainfall in the Southern California area in the last 150 years are listed in Table 7-4 below. Many of these storms are associated with El Niño or La Niña events. Thunderstorms can occur at any time, but are usually more prevalent in the higher mountains during the summer, and usually impact relatively small areas.

Table 7-4: Historical Tropical Storms that Affected Southern California

Month-Year	Date(s)	Source of Rain; Southern California	Rainfall
Oct. 1858	2nd & 3rd	The only known historical hurricane that made a landfall in Southern California; 75-mph winds estimated in San Diego; tropical storm winds along coastline north to Long Beach; intense rain reported from San Diego to Santa Barbara.	> 7"
July 1902	20th & 21st	Deserts and southern mountains. El Niño of 1901-02.	up to 2"
Aug. 1906	18th & 19th	Deserts and southern mountains. El Niño of 1905-06.	up to 5"
Sept. 1910	15th	Mountains of Santa Barbara County.	2"
Aug. 1915	26th	Deserts of Southern California, and into Riverside. El Niño of 1914-15.	1"
Aug. 1921	20th & 21st	Deserts and southern mountains. La Niña of 1920-21.	up to 2"
Sept. 1921	30th	Deserts. La Niña of 1920-21.	up to 4"
Sept. 1929	18th	Southern mountains and deserts.	up to 4"
Sept. 1932	28th - Oct 1st	Mountains and deserts, 15 fatalities in the Tehachapi area. El Niño of 1932-33.	up to 7"
Aug. 1935	25th	Southern valleys, mountains and deserts.	up to 2"
Aug. 1936	9th	Locally heavy rainfall in the mountains surrounding Los Angeles.	n/a

Month-Year	Date(s)	Source of Rain; Southern California	Rainfall
Sept. 1939 (during El Niño of 1938-39)	4th - 7th	Remnants of a hurricane; impacted the southern mountains, and the southern and eastern deserts.	up to 7"
	11th & 12th	Deserts, central and southern mountains.	up to 4"
	19th - 21st	Deserts, central and southern mountains.	up to 3"
	25th	Tropical cyclone that made a landfall in San Pedro, with sustained winds of 50 mph. Only known tropical cyclone to make a landfall in Southern California. 93 people died; 45 onshore and 48 offshore, at sea. Ten houses washed away in Belmont Shores.	5" in LA basin
		Surrounding mountains.	6 to 12"
Sept. 1941		Southern mountains and deserts. Strong El Niño of 1940-1941.	up to 1"
Sept. 1945	9th & 10th	Central and southern mountains	up to 2"
Sept. 1946	30th - Oct 1st	Southern mountains. El Niño of 1946-47.	up to 4"
Aug. 1951	27th - 29th	Southern mountains and deserts; many roads washed out in the Imperial Valley. El Niño of 1951-52.	2 to 5"
Sept. 1952	19th - 21st	Central and southern mountains. El Niño of 1951-52.	up to 2"
July 1954	17th - 19th	Deserts and southern mountains. El Niño of 1953-54.	up to 2"
July 1958	28th & 29th	Deserts and southern mountains. El Niño of 1957-58.	up to 2"
Sept. 1959	11th	Spotty rainfall in the deserts and mountains.	up to ½"
Sept. 1960	9th & 10th	Hurricane Estelle dissipated west of Central Baja California; southern mountains at and near Julian.	3.40"
Sept. 1963	17th - 19th	Tropical storm Katherine made landfall in northern Baja California; impacted central and southern mountains. El Niño of 1963-64.	up to 7"
Sept. 1967	1st - 3rd	Hurricane Katrina in Baja California; impacted southern mountains and deserts.	2"
Sept. – Oct. 1971	30th – Oct. 1st	Caribbean-Sea Hurricane Irene crossed Nicaragua; reformed in the eastern Pacific as Hurricane Olivia, which made landfall in Central Baja California; impacted southeast deserts. La Niña of 1970-71.	up to 1"
Sept. 1972	3rd	Remnants of Hurricane Hyacinth made landfall between Los Angeles and San Diego with 25-mph winds and rainfall in the central and southern mountains. El Niño of 1972-1973.	up to 1"
Oct. 1972	6th	Hurricane Joanne made landfall in northern Baja; maintained tropical storm strength into Arizona; rain in southeast deserts. El Niño of 1972-1973.	up to 2"

Month-Year	Date(s)	Source of Rain; Southern California	Rainfall
Sept. 1976	10th & 11th	As a result of the tropical storm Kathleen; impacted the central and southern mountains; sustained winds of 57 mph at Yuma. Killed 12 people in the U.S.; 70-80% of Ocotillo was destroyed; caused millions of dollars in damage. El Niño of 1976-1977.	6 to 12"
Aug. 1977	n/a	Hurricane Doreen dissipated over the Southern California coastal waters. Widespread flooding; extensive crop damage. In Los Angeles and south, up to 2" of rain.	2"
		Mountains. El Niño of 1977-78.	up to 8"
Oct. 1977	6th & 7th	Remnants of Hurricane Heather tracked into southern Arizona; impacted southern mountains and deserts.	up to 2
Sept. 1978	5th & 6th	Remnants of Hurricane Norman impacted the mountains. El Niño of 1977-78.	> 3"
June 1980	29th & 30th	Remnants of Hurricane Celia; scattered rainfall in Santa Barbara.	up to ½"
Sept. 1982	17th & 18th	Remnants of Hurricane Norman; with scattered rainfall in the southern mountains and deserts. Strong El Niño of 1982-83.	up to 1"
Sept. 1982	24th - 26th	Remnants of Hurricane Olivia; impacted the mountains. Strong El Niño of 1982-83.	up to 4"
Sept. 1983	20th & 21st	Hurricane Manuel dissipated off west coast of northern Baja California; impacted the southern mountains and deserts. Strong El Niño of 1982-83.	up to 3"
Oct. 1983	7th	Remnants of Hurricane Priscella scattered light rain across Southern California. Strong El Niño of 1982-83.	n/a
Sept. 1984	10th & 11th	Hurricane Marie dissipated off the west coast of northern Baja California; scattered rain in coastal areas.	n/a
Aug. 1997	17th – 19th	Tropical storm Ignacio dissipated near the south-central California coast with gale-force winds over coastal waters. Strong El Niño of 1997-1998.	n/a
Sept. 1997	N/a	Hurricane Linda, the strongest storm recorded in the eastern Pacific with 180-mph winds, threatened to come ashore in California as a subtropical storm. Storm turned away, but caused high surf, waves 18 ft. high, showers and thunderstorms. Strong El Niño of 1997-1998.	n/a
Sept. 1997	25th	Hurricane Nora crossed into Southern California and Arizona from Baja California. Brought heavy rain to parts of the region, causing millions of dollars in damage to agriculture.	

Month-Year	Date(s)	Source of Rain; Southern California	Rainfall
Sept. 2004	10th – 19th	Mid-level moisture from hurricane Javier spread over northern Mexico, and southwestern US.	n/a
July 2006	31st	Remnants of tropical storm Emilia brought rain to Southern California that helped extinguish the House Fire.	
Sept. 2007	20 – 22nd	Thunderstorms and showers; flooding watch in Santa Catalina Island; rain throughout the Southern California area.	n/a
July 2012	18th – 20th	Remnants of Hurricane Fabio generated scattered showers and thunderstorms in the Los Angeles basin.	na
August 2013	25th – 26th	Moisture from the remnants of tropical storm Ivo caused flash floods and mudslides in San Bernardino County and Arizona. One motorist drowned in Needles.	3-4"
http://www.fema.gov/nwz97/eln_scal.shtm; http://usatoday.com/weather/whhcalif.htm; http://www.nhc.noaa.gov; Chenoweth and Landsea, 2004 (on the 1858 Hurricane); http://www.nasa.gov/topics/earth/features/earth20121017.htm; http://en.wikipedia.org/wiki/List_of_California_hurricanes			

Tides

Tides are regular changes in the ocean water levels caused by the gravitational pull of the Moon and Sun acting on the oceans' surface. The changing tide at a given location results from the interaction between the changing positions of the Moon and Sun, the effects of the Earth's rotation, and the local bathymetry or shape of the ocean floor.

Tides are either semidiurnal (two high waters and two low waters every day), or diurnal (one high water and one low water per day). In the east coast of the United States, tides are semidiurnal, whereas on the west coast, significant tidal fluctuations occur once and twice daily, twice monthly, twice yearly, every 4.4 years, and every 18.6 years (Flick, 1998). In California, the two high tides and two low tides that occur daily are unequal in amplitude: The lower-low tide of the day generally follows the higher-high tide seven or eight hours later. These semi-diurnal differences in the height between the high and low water levels over about half a day vary in a two-week cycle. Around new and full moon, when the Sun, Moon and Earth are in line, the tidal forces due to the Sun reinforce those due to the Moon, creating a maximum in tidal range called "spring tides" or "springs" (meaning "to jump" or "to leap up"). When the Moon is at first or third quarter, and it is not in line with the Sun, the effects due to the gravitational pull from the Sun partially cancel those of the Moon, resulting in a minimum tide range. This is called the "neap tide" or "neaps." The distance between the Moon and the Earth also has an effect on tide heights; as a result one spring tide per month is usually higher than the other. In Southern California, the highest monthly tides are those in the winter and summer.

Given that tides affect the depth of the water in both the ocean and estuaries and create oscillating currents known as tidal streams that have an impact on navigation, recreation, and potential flooding of coastal areas, tidal tables that show the predicted tide heights at a given location are published for the benefit of a variety of users (see www.mobilegeographics.com or www.saltwatertides.com for examples). In Newport Beach, the Municipal Operations Department refers to tidal tables on a daily basis to assess whether or not they need to close some or all of the valves around the low-lying areas of the City to prevent flooding from high tides. If the tides are expected to be higher than 5.2 feet, City personnel close some of the valves; if the tides are expected to be more than 7 feet high, they close all of the 86 valves in the City (Jim Auger, personal communication, 2008). Since most of these gate valves are opened and closed manually, this takes some time. This function is especially important in the winter, when the extreme monthly higher-high tides generally occur in the early morning (Flick and Cayan, 1984; Flick, 1998; Flick, 2007). This means that preparations by City personnel to prevent flooding often need to be made at night. If the higher-high tides occur together with a winter storm, the resulting storm surge can overwhelm the storm drain and valves system in the City. Fortunately, this does not occur often.

In Southern California, peak storm surges associated with El Niño events occurred in January and March 1983, and in February 1998. The late January 1983 sea levels were the highest that had been recorded in the region until then, with gauges in San Diego and Los Angeles measuring levels at 9.6 and 12.2 inches, respectively, above the predicted high tide. The storm surge associated with the 1998 storms is a record high (1.8 feet in Los Angeles; 1.6 feet in Newport Beach); fortunately, the storm coincided with the neap tides in Southern California, greatly reducing coastal flooding and damage (Flick, 1998). The January 2005 storms, on the other hand, generated a slightly lower storm surge of 1 to 1.2 feet, but coincided with higher tides, resulting in flooding of many low-lying areas in the City, as discussed previously. More recently, on December 12-15, 2012, a winter storm coincided with unusually high tides of almost 8 feet, resulting in coastal flooding in Orange County, from Seal Beach south to Newport Harbor. On the 13th, tide levels peaked around 8.4 feet, which was about 3 to 6 inches higher than the predicted high tide, attributed to the approaching low pressure area. The high tide, combined with runoff from the rain caused flooding of Pacific Coast Highway in and near Huntington Beach, along Marcus Avenue in Newport Harbor, and near the intersection of Newport Boulevard and 26th Street. Some homes were flooded with nearly one foot of water. Similar flooding was observed on the morning of the 14th, with the tide reaching nearly 8 feet (https://www.ncdc.noaa.gov/stormevents/eventdetails.jsp?id=423426).

Geography and Geology

The local hills and mountains are very steep and consist of rock types that are fairly impervious to water. Consequently, little precipitation infiltrates the ground; rainwater instead flows across the surface as runoff, collecting in the major drainages that pass through the City. When a major storm moves in, water collects rapidly and runs off quickly, making a steep, rapid descent from the hills into man-made and natural channels within developed areas. Because of the steep terrain, scarcity of vegetation, and the constant shedding of debris from the hill slopes, flood flows often carry large amounts of mud, sand, and rock fragments. Sheet flow occurs when the capacities of the existing channels (either natural or man-made) are exceeded and water flows over and into the adjacent areas.

The Southern California area has been shaped by erosion and sedimentation for millennia. Most of the mountains that ring the valleys and coastal plain have and are being uplifted along movement on faults; this movement has fractured the bedrock, allowing for their brittle slopes to be readily eroded. Rivers and streams have then carried boulders, rocks, gravel, sand, and silt down these slopes to the valleys and coastal plain. Over time, these sediments have collected in the valley bottoms, so that locally these sediments are as much as twenty thousand feet thick. This sediment generally acts as a sponge, absorbing vast quantities of water received as precipitation in those years when heavy rains follow a dry period. But like a sponge that is near saturation, the same soil fills up rapidly when a heavy rain follows a period of relatively wet weather. So, in some years of heavy rain, flooding is minimal because the ground is relatively dry, whereas the same amount of rain following a wet period, when the ground is already saturated, can cause extensive flooding.

Built Environment

The northern two-thirds of Newport Beach, as a good portion of Orange County, are essentially built out. This leaves precious little open land to absorb rainfall. This lack of open ground forces water to remain on the surface and accumulate rapidly. If it were not for the massive flood control system that has been built over the years, with its concrete-lined rivers and stream beds, flooding in the Santa Ana River basin would be a much more common occurrence. And the tendency is towards even less and less open land. In-fill building is becoming a much more common practice in many areas: Developers tear down older homes, which typically cover up to 40 percent of the lots that they sit on, and replace each of them with three or four town homes or apartments, which may cover 90 to 95 percent of the lot. This increase in impervious surfaces (including concrete walkways, and roofs) results in a direct increase in runoff.

Another potential reason for recurrent storm flooding in developed areas is "asphalt creep." The street space between the curbs of a street is a part of the flood control system. Water leaves the adjacent properties and accumulates in the streets, where it is directed towards the underground portion of the flood control system. The carrying capacity of a given street is determined by the width of the street and the height of the curbs along the street. Often, when streets are being resurfaced, a one- to two-inch layer of asphalt is laid down over the existing asphalt. This added layer of asphalt subtracts from the rated capacity of the street to carry water. Thus the original engineered capacity of the entire storm drain system is marginally reduced over time. Subsequent re-paving of the street further reduces its engineered capacity.

When structures or fill are placed in the floodway or floodplain, water is displaced. Development raises the river levels by forcing the river to compensate for the flow space obstructed by the inserted structures and/or fill. When structures or materials are added to the floodway or floodplain and no fill is removed to compensate, serious problems can arise. Flood waters may be forced away from historic floodplain areas. As a result, other existing floodplain areas may experience floodwaters that rise above historic levels. Local governments must require engineer certification to ensure that proposed developments will not adversely affect the flood-carrying capacity of the Special Flood Hazard Area (SFHA). Displacement of only a few inches of water can mean the difference between no structural damage occurring in a given flood event, and the inundation of many homes, businesses, and other facilities. Careful attention should be given to development that occurs within the floodway to ensure that structures are prepared to withstand base flood events.

In highly urbanized areas, increased paving can lead to an increase in volume and velocity of runoff after a rainfall event, exacerbating the potential flood hazards. Care should be taken in the development and implementation of storm water management systems to ensure that these runoff waters are dealt with effectively.

How Are Flood-Prone Areas Identified?

The Federal Emergency Management Agency (FEMA) is mandated by the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973 to evaluate flood hazards. To promote sound land use and floodplain development, FEMA provides Flood Insurance Rate Maps (FIRMs) for local and regional planners. Flood risk information presented on FIRMs is based on historic, meteorological, hydrologic, and hydraulic data, as well as topographic surveys, open-space conditions, flood control works, and existing development.

Rainfall-runoff and hydraulic models are utilized by the FIRM program to analyze flood potential, adequacy of flood protective measures, surface-water and groundwater interchange characteristics, and the variable efficiency of mobile (sand bed) flood channels. It is important to realize that FIRMs only identify potential flood areas based on the conditions at the time of the study, and do not consider the impacts of future development. To prepare FIRMs that illustrate the extent of flood hazards in a flood-prone community, FEMA conducts engineering studies referred to as Flood Insurance Studies (FISs). Using information gathered in these studies, FEMA engineers and cartographers delineate Special Flood Hazard Areas (SFHAs) on FIRMs. SFHAs are those areas subject to inundation by a "**base flood**" which FEMA sets as a 100-year flood (see definitions below).

Flood Insurance Rate Maps (FIRM) and Flood Insurance Studies (FIS) Floodplain maps are the basis for implementing floodplain regulations and for delineating flood insurance purchase requirements. A Flood Insurance Rate Map (FIRM) is the official map produced by FEMA which delineates SFHA in communities where NFIP regulations apply. FIRMs are also used by insurance agents and mortgage lenders to determine if flood insurance is required and what insurance rates should apply.

Water surface elevations are combined with topographic data to develop FIRMs. FIRMs illustrate areas that would be inundated during a 100-year flood, floodway areas, and elevations marking the 100-year-flood level. In some cases they also include base flood elevations (BFEs) and areas located within the 500-year floodplain. Flood Insurance Studies and FIRMs produced for the NFIP provide assessments of the probability of flooding at a given location. FEMA conducted many Flood Insurance Studies in the late 1970s and early 1980s. These studies and maps represent flood risk at the point in time when FEMA completed the studies. However, it is important to note that not all 100-year or 500-year floodplains have been mapped by FEMA.

FEMA flood maps are not entirely accurate. These studies and maps represent flood risk at the point in time when FEMA completed the studies, and does not incorporate planning for floodplain changes in the future due to new development. Although FEMA is considering changing that policy, it is optional for local communities.

Flood Mapping Methods and Techniques

Although many communities rely exclusively on FIRMs to characterize the risk of flooding in their area, there are some flood-prone areas that are not mapped but remain susceptible to flooding. These areas include locations next to small creeks, local drainage areas, and areas susceptible to man-made flooding.

In order to address this lack of data, jurisdictions can take efforts to develop more localized flood hazard maps. One method that has been employed includes using high-water marks from flood events or aerial photos, in conjunction with the FEMA maps, to better reflect the true flood risk. The use of GIS (Geographic Information System) is becoming an important tool for flood hazard mapping. FIRM maps can be imported directly into GIS, which allows for GIS analysis of flood hazard areas.

Communities find it particularly useful to overlay flood hazard areas on tax assessment parcel maps. This allows a community to evaluate the flood hazard risk for a specific parcel during review of a development request. Coordination between FEMA and local planning jurisdictions is the key to making a strong connection with GIS technology for the purpose of flood hazard mapping.

FEMA and the Environmental Systems Research Institute (ESRI), a private company, have formed a partnership to provide multi-hazard maps and information to the public via the Internet. ESRI produces GIS software, including ArcViewC9 and ArcInfoC9. The ESRI web site has information on GIS technology and downloadable maps. The hazards maps provided on the ESRI site are intended to assist communities in evaluating geographic information about natural hazards. Flood information for most communities is available on the ESRI web site. Visit www.esri.com for more information.

The NFIP also reduces flood losses through regulations that focus on building codes and sound floodplain management. In the City of Newport Beach, the NFIP and related building code regulations went into effect on September 1, 1978 (City ID No. 060227). NFIP regulations (44 Code of Federal Regulations (CFR) Chapter 1, Section 60, 3) require that all new construction in floodplains must be elevated at or above base flood level.

Flood Terminology

Floodplain

A floodplain is a land area adjacent to a river, stream, lake, estuary, or other water body that is subject to flooding. This area, if left undisturbed, acts to store excess floodwater. The floodplain is made up of two sections: the floodway and the flood fringe.

100-Year Flood

The 100-year flooding event is the flood having a one percent chance of being equaled or exceeded in magnitude in any given year. Contrary to popular belief, it is not a flood occurring once every 100 years. The 100-year floodplain is the area adjoining a river, stream, or watercourse covered by water in the event of a 100-year flood. A **100-year flood** is defined by looking at the long-term average period between floods of a certain size, and identifying the size of flood that has a 1 percent chance of occurring during any given year. This base flood has a 26 percent chance of occurring during a 30-year period, the length of most home mortgages. However, a recurrence interval such as “100 years” represents only the long-term average period between floods of a specific magnitude; rare floods can in fact occur at much shorter intervals or even within the same year.

Floodway

The floodway is one of two main sections that make up the floodplain. Floodways are defined for regulatory purposes. Unlike floodplains, floodways do not reflect a recognizable geologic feature. For National Flood Insurance Program (NFIP) purposes, floodways are defined as the channel of a river or stream, and the overbank areas adjacent to the channel. The floodway carries the bulk of the floodwaters downstream and is usually the area where water velocities and forces are the greatest. NFIP regulations require that the floodway be kept open and free from development or other structures that would obstruct or divert flood flows onto other properties.

In accordance with NFIP requirements, Newport Beach prohibits all development in the floodway, but this regulation is not retroactive, and as a result, there are older structures built therein. For example, all of Balboa Island is located in the floodway. The NFIP floodway definition is "the channel of a river or other watercourse and adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than one foot.” Floodways are not mapped for all rivers and streams but are generally mapped in developed areas.

Flood Fringe

The flood fringe refers to the outer portions of the floodplain, beginning at the edge of the floodway and continuing outward. Generally, the flood fringe is defined as "the land area which is outside of the stream flood way but is subject to periodic inundation by regular flooding.” This is the area where development is most likely to occur, and where precautions to protect life and property need to be taken.

Development

For floodplain ordinance purposes, development is broadly defined as "any man-made change to improved or unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation, or drilling operations located within the area of special flood hazard." The definition of development for floodplain purposes is generally broader and includes more activities than the definition of development used in other sections of local land use ordinances.

Base Flood Elevation (BFE)

The term "Base Flood Elevation" refers to the elevation (normally measured in feet above sea level) that the base flood is expected to reach. Base flood elevations can be set at levels other than the 100-year flood. Some communities choose to use higher frequency flood events as their base flood elevation for certain activities, while using lower frequency events for others. For example, for the purpose of storm water management, a 25-year flood event might serve as the base flood elevation, whereas the 500-year flood event may serve as base flood elevation for the tie down of mobile homes. The regulations of the NFIP focus on development in the 100-year floodplain.

Storm Flooding Characteristics

Four primary types of storm-induced flooding have historically affected the coastal Southern California area, including the City of Newport Beach: riverine flooding, urban flooding, debris flows, and coastal flooding (see descriptions below). In Newport Beach, specifically, storm flooding hazards can be classified into three general categories: 1) flash flooding from small, natural channels, 2) more moderate and sustained flooding from the Santa Ana River and San Diego Creek, and 3) coastal flooding associated with storm surges.

Riverine Flooding

Riverine flooding is the overbank flooding of rivers and streams. This process in a natural environment adds sediment and nutrients to the flooded area, cyclically enhancing the fertility of the soils, which is why floodplains have been the breadbaskets of civilizations through the ages. However, large floods have the potential to cause significant damage to man-made structures and cause significant loss of life. Flooding in large river systems typically results from large-scale weather systems that generate prolonged rainfall over a wide geographic area, causing flooding in hundreds of smaller streams, which then drain into the major rivers.

Shallow-area flooding is a special type of riverine flooding. FEMA defines shallow flood hazards as areas that are inundated by the 100-year flood with flood depths of only one to three feet. These areas are generally flooded by low-velocity sheet flows of water.

Urban Flooding

As land is converted from agricultural fields or woodlands to roads and parking lots, it loses its ability to absorb rainfall. Urbanization of a watershed changes the hydrologic systems of the basin. Heavy rainfall collects and flows faster on impervious concrete and asphalt surfaces. The water moves from the clouds, to the ground, and into streams at a much faster rate in urban areas. Adding these elements to the hydrological systems can result in floodwaters that rise very rapidly and peak with violent force. The flooding of developed areas often occurs when the amount of water generated from rainfall and runoff exceeds the storm water system's capability to remove it.

Newport Beach, like most cities, has a high concentration of impervious surfaces that either collect water, or concentrate the flow of water in channelized or man-improved channels. The San Joaquin

Hills in the eastern part of the City consist of sedimentary rock types that are fairly impervious to water so little precipitation infiltrates the ground; rainwater instead flows along the surface as runoff. When a major storm moves in, water collects rapidly and runs off quickly, making a steep, rapid descent from the hills into manmade and natural channels in the built environment and onto the marine terraces along the coast. During periods of urban flooding, streets can become swift moving rivers and basements and other low-lying areas can fill with water. Storm drains may also back up with vegetation and debris causing additional, localized flooding.

Debris Flows

Another flood related hazard that can affect certain parts of the Southern California region is debris flows. Debris flows most often occur in mountain canyons and at the foothills of the mountains that serve as backdrop to the area. However, any hilly or mountainous area with intense rainfall and the proper geologic conditions may experience one of these very sudden and devastating events.

Debris flows, sometimes referred to as mudslides, mudflows, or debris avalanches, are common types of fast-moving landslides that generally occur during periods of intense rainfall (or rapid snow melt). They usually start on steep hillsides as shallow landslides that liquefy and accelerate to speeds that are typically about 10 miles per hour, but can exceed 35 miles per hour. The consistency of debris flows ranges from watery mud to thick, rocky mud that can carry large items such as boulders, trees, and cars. Debris flows from many different sources can combine in channels, and their destructive power may be greatly increased. They continue flowing down hills and through channels, growing in volume with the addition of water, sand, mud, boulders, trees, and other materials. When the flows reach flatter ground, the debris spreads over a broad area, sometimes accumulating in thick deposits that can wreak havoc in developed areas.

Coastal Flooding

Flooding of coastal areas often occurs during periods of stormy weather, due to storm surges. A **storm surge** is an abnormal rise in sea water level associated with hurricanes and other storms at sea. Surges result from strong on-shore winds and/or intense low-pressure cells associated with ocean storms. Water level is controlled by wind, atmospheric pressure, existing astronomical tide, waves and swell, local coastal topography and bathymetry, and the storm's proximity to the coast. Flooding of deltas and other low-lying coastal areas is exacerbated by the influence of tidal action, localized storm waves, and frequent channel shifts.

Most often, destruction by storm surge is attributable to:

- Wave impact and the physical shock on objects associated with the *passing* of the wave front. The water may lift and carry objects to different locations.
- *Direct impact* of waves on fixed structures. This tends to cause most of the damage.
- Failure of private and public sea walls, resulting in significant flooding.
- *Indirect impacts,* such as flooding and the undermining of major infrastructure (such as highways and railroads).

For example, unusually severe storms in June, July and August of 1920 caused extensive damage to the west jetty in Newport Beach. Tidal currents swept the sand from beneath the toes of the jetty's slopes, and the rocks sank into the ocean floor, which lowered the crest of the jetty so that two large gaps appeared in it at times of high tide. Storm-generated swells, especially when combined with tidal action also have the potential to cause damage. In the Southern California area, including Newport Beach, localized flooding and accelerated rates of coastal erosion have occurred when storms are combined with high tides. This occurred during the 1977-1978, 1983, 1988, 2005 and

2010 storms, when the combination of high waves, local storm surges and high tides damaged several coastal structures in Southern California.

According to Walker et al. (1984), the 1977-78 storms did not damage the piers and jetties at Newport Beach. During the storms in 1988, however, the high water extended to the first row of houses behind the groin field at Newport Beach causing minor flood damage to these structures (Pipkin et al., 1992). Although the brunt of the February 1998 storms did not strike during high tide, the storm surge was such that the Newport pier was damaged. The winter storms of 2009-2010 caused extensive erosion up and down the Southern California coastline, in many areas touted as the "worst in a decade" (Los Angeles Times, 04/02/2010; http://articles.latimes.com/2010/apr/02/local/la-me-vanishing-beaches2-2010apr02).

Interestingly, recent studies (Ruggiero et al., 2010; Seymour, 2011) have shown that average wave heights along the west coast have gradually increased during the past several decades, based on an analysis of long-term wave data from buoys located off the coast. The data show that between 1996 and 2010, 75 storm events generating waves 16 feet high and higher occurred along the Southern California coastline, from Pt. Concepcion south to the Mexican border, whereas in the period between 1984 and 1995, there were only 11 storm events generating waves of that size (Russell and Griggs, 2012, based on data by Seymour, 2011). The reasons behind this sharp increase in wave height are poorly understood at this time; increases in ocean water temperature, changes in storm tracks, higher wind speeds, and more intense winter storms are all thought to be possible factors. Nevertheless, an increase in storms generating large waves off the coast of Newport Beach means an increase in coastal erosion rates, with the potential for significant damage to infrastructure and private property.

Tsunami and Rogue Wave Flooding

A **tsunami** is a sea wave caused by any large-scale disturbance of the ocean floor that occurs in a short period of time and causes a sudden displacement of water. Tsunamis can travel across the entire Pacific Ocean basin, or they can be local. For example, an earthquake off the coast of Japan can generate a tsunami that causes substantial damage in Hawaii and Northern California. These distantly generated tsunamis are also referred to as teletsunamis. This report addresses the potential for both teletsunamis and locally generated tsunamis impacting the Newport Beach coastline.

Large-scale tsunamis are not single waves, but rather a long train of waves. The most frequent causes of tsunamis are shallow underwater earthquakes and submarine landslides, but tsunamis can also be caused by underwater volcanic explosions, oceanic meteor impacts, and even underwater nuclear explosions. Tsunamis are characterized by their length, speed, low period, and low observable amplitude: the waves can be up to 200 km (125 mi) long from one crest to the next, they travel in the deep ocean at speeds of up to 950 km/hr (600 mi/hr), and have periods of between 5 minutes and up to a few hours (with most tsunami periods ranging between 10 and 60 minutes). Their height in the open ocean is very small, a few meters at most, so they pass under ships and boats undetected (Garrison, 2002), but may pile up to heights of 30 m (100 ft) or more on entering shallow water along an exposed coast, where they can cause substantial damage. The highest elevation that the water reaches as it runs up on the land is referred to as wave runup, uprush, or inundation height (McCulloch, 1985; Synolakis et al., 2002). Inundation refers to the horizontal distance that a tsunami wave penetrates inland (Synolakis et al., 2002).

Earthquake-generated tsunamis have been studied more extensively than any other type. Researchers have found that there is a correlation between the depth and size of the earthquake and the size of the associated tsunami: the larger the earthquake and the shallower its epicenter, the larger the resulting tsunami (Imamura, 1949; Iida, 1963, as reported in McCulloch, 1985). The size of the tsunami is also related to the volume of displaced sea floor (Iida, 1963). Given these correlations, several researchers in the last decades have modeled tsunami runups for various areas along the Pacific Ocean, including in the western United States (Houston, 1980; Brandsma et al., 1978; Synolakis, 1987; Titov and Synolakis, 1998; and many others – refer to www.usc.edu/dept/tsunamis/tsupubs and www.tsunamiresearchcenter.com/publications/).

Rogue waves are very high waves, as much as tens of meters high, but, compared to tsunamis, they are very short from one crest to the next, typically less than 2 km (1.25 mi) long. Rogue waves arise unexpectedly in the open ocean, and their generating mechanism is a source of controversy and active research. Rogue waves are unpredictable and therefore it is nearly impossible to plan for them. Some theories on rogue wave formation include:

- Strong currents that interact with existing swells making the swells much higher;
- A statistical aberration that occurs when a number of waves just happen to be in the same place at the same time, combining to make one big wave;
- The result of a storm in the ocean where the wind causes the water surface to be rough and choppy, creating very large waves.

Notable Tsunamis and Rogue Waves in the Newport Beach Area

In the Pacific Basin, most tsunamis originate in six principal regions, all of which have prominent submarine trenches. Of the six regions, only three have produced major tsunami damage along the California coastline in historical times. These are the Aleutian (Gulf of Alaska) region, the region off Chile, in South America (CDMG, 1976), and the region off eastern Japan, as evidenced by the March 2011 Tohoku-oki event. Southern California is generally protected from teletsunamis by the Channel Islands, which deflect east- and northeast-trending waves, and by Point Arguello, which deflects waves coming in from the continental area of Alaska (see Map 7-5). Tsunamis generated by local earthquakes or landslides have historically posed only a minor, localized risk to Southern California. However, the record also shows that the highest sea waves recorded in the Southern California area were caused by a locally generated tsunami, the 1812 Santa Barbara event.

Although the historical record for Southern California is short, to date approximately 55 tsunamis have been recorded in Southern California since the early 1800s (see Table 7-5). Given that instrumented tidal measurements in Southern California were first made in 1854, wave heights for pre-1854 events are estimated based on historical accounts.

Most records are for the San Diego and Los Angeles areas, with only a few events actually mentioned in the Orange County area. Most of the recorded tsunamis produced only small waves between 0.15 and 0.3 m (0.5 – 1 ft) high that did not cause any damage, but eight are known to have caused damage in the Southern California area. Those events are shown in bold in Table 7-5, and are described further in the paragraphs below.

Map 7-5: Wave Exposure Map for Newport Beach

(Source: U.S. Army Corps of Engineers, Los Angeles District, November 1993, Condition Survey for Entrance Jetties, Newport Bay Harbor, Orange County, California.)

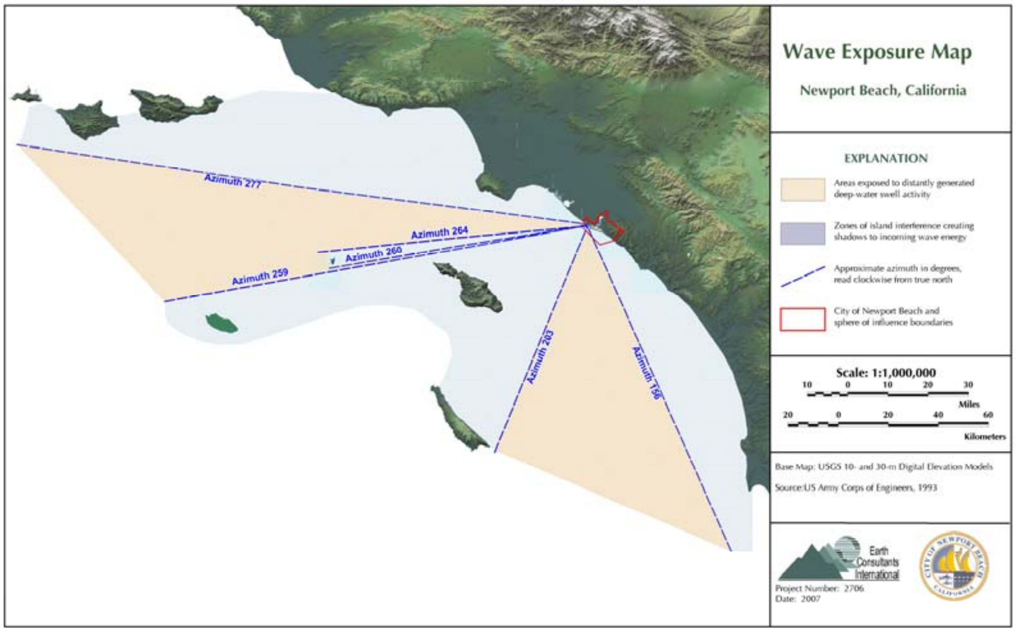


Table 7-5: Historical Tsunami Record for Southern California - 1812 to Present

(Tsunamis that caused damage in Southern California are in bold)

Date	Source	Wave Height
December, 1812	**Southern California; earthquake or landslide in Santa Barbara Channel?**	**Santa Barbara: ~2-3 m (6.6-9.8 ft); Ventura: ~2-3 m (6.6-9.8 ft)**
November, 1853	Kuril Islands	Unknown; possibly observed in San Diego
May, 1854	Southern California; possibly same as July or December events	Unknown; observed in San Diego
July, 1854	Unknown; possible meteorological origin	San Diego: ~0.3 m (~1 ft)
December 23, 1854	Japan	San Diego: < 0.1 m (0.3 ft)
December 24, 1854	Japan	San Diego: 0.1 m (0.3 ft)
July, 1855	Southern California; possible offshore landslide caused by earthquake in Los Angeles	Unknown; large waves reported at Point San Juan; 2 unusually heavy sea waves in San Juan Capistrano.
April, 1868	Hawaii	San Diego: 0.1 m (0.3 ft)
August, 1868	Chile	San Diego: 0.3 – 0.8 m (0.6-2.6 ft); San Pedro: 1.8 m (5.9 ft) Wilmington: 1.8 m (5.9 ft)
August, 1872	Aleutian Islands	San Diego: < 0.1 m (0.3 ft)
May, 1877	Chile	San Pedro: 1 m (3.3 ft); Wilmington: 1 m (3.3 ft); Gaviota: 3.7 m (12.1 ft)
August, 1879	Southern California; possible undersea landslide caused by earthquake in San Fernando area	Unknown; tsunami reported at Santa Monica

Date	Source	Wave Height
December, 1899	Southern California; Underwater landslide generated by earthquake in San Jacinto area?	Unknown; large wave reported along Southern California coast
February, 1902	El Salvador-Guatemala	Unknown; large wave reported in San Diego
January, 1906	Ecuador	Unknown; reported in San Diego
August, 1906	Chile	San Diego: 0.1 m (0.3 ft)
May, 1917	South Pacific	Unknown; large waves reported in La Jolla
June, 1917	South Pacific	Unknown; reported in San Diego
April, 1919	South Pacific	Unknown; reported in San Diego
November, 1922	Chile	San Diego: 0.2 m (0.7 ft)
February, 1923	Kamchatka	San Diego: 0.2 m (0.7 ft)
October, 1925	Unknown; possible meteorological origin or submarine volcanic event	Long Beach: 0.34 m (0.1 ft)
January, 1927	**Southern California; possible submarine landslide caused by earthquake in Imperial Valley**	**Unknown; large waves reported along Southern California coast: 1.8 m (5.9 ft) runup at Surf; 1.5 m (4.9 ft) runup at Port San Luis.**
November, 1927	Central and Southern California; offshore earthquake off Point Arguello, possibly on the Hosgri fault	La Jolla: 0.2 – 0.3 m (0.7 – 1 ft); Surf: 1.8 m (5.9 ft) Port San Luis: 1.5 m (4.9 ft)
June, 1928	Southern Mexico	La Jolla: < 0.1 m (0.3 ft)
August, 1930	Southern California; offshore earthquake in Santa Monica Bay	Santa Monica: 0.6 m (1.9 ft)
March, 1933	Japan	Los Angeles: 0.2 m (0.7 ft); Santa Monica < 2.0 m (6.6 ft)
March, 1933	Southern California; Long Beach Earthquake	Long Beach: 0.1 m? (0.3 ft)
August, 1934	**Unknown; possibly caused by earthquake or submarine landslide near Balboa, or of meteorological origin**	**Newport Beach: 3 m rise (9.8 ft); 9-12 m (30 –39 ft) waves**
April, 1943	Chile	San Diego: 0.1 m (0.3 ft)
December, 1944	Japan	San Diego: < 0.1 m (0.3 ft)
April, 1946	Aleutian Islands	Avila: 1.2 m (3.4 ft)
March, 1957	**Aleutian Islands**	**San Diego: 0.2 – 1.0 m (0.7–3.3 ft)**
May, 1960	**Chile**	**Santa Monica: 1.4 m (4.6 ft)**
May, 1964	**Gulf of Alaska**	**Santa Monica: 1.0 m (3.3 ft)**
February, 1965	Aleutian Islands	Santa Monica: 0.08 m (0.3 ft)
May, 1968	Japan	Santa Monica: 0.2 m (0.7 ft); Long Beach: 0.1 m (0.3 ft)
May, 1971	South Pacific	Los Angeles: 0.05 m (0.2 ft)
November, 1975	Hawaii	La Jolla: 0.1 m (0.3 ft)
June, 1977	South Pacific	Los Angeles: 0.05 m (0.2 ft); Long Beach: 0.12 m (0.4 ft)
1979 and 1989	Unknown source – affected Santa Monica Bay	Local oscillations (?)
July 30, 1995	North Chile	Los Angeles: 0.05 m (0.2 ft); San Diego: 0.05 m (0.2 ft)
June 23, 2001	South Peru	Los Angeles: 0.10 m (0.3 ft) La Jolla: 0.10 m (0.3 ft)

Date	Source	Wave Height
December 26, 2004	Off west coast of Sumatra	Los Angeles: 0.27 m (0.9 ft) La Jolla: 0.12 m (0.4 ft) San Diego: 0.32 m (1.05 ft) Santa Monica: 0.41 m (1.35 ft)
May 3, 2006	Tonga	La Jolla: 0.04 m (0.13 ft) Los Angeles: 0.08 m (0.26 ft) Santa Monica: 0.10 m (0.3 ft)
November 15, 2006	South Kuril Islands, Russia	Los Angeles: 0.11 m (0.36 ft) La Jolla: 0.13 m (0.43 ft) Santa Monica: 0.15 m (0.5 ft)
April 1, 2007	Solomon Islands	San Diego: 0.1 m (0.3 ft) Santa Monica: 0.11 m (0.36 ft)
August 15, 2007	South Peru	San Diego: 0.05 m (0.16 ft) Los Angeles: 0.06 m (0.2 ft) Santa Monica: 0.07 m (0.23 ft)
September 29, 2009	Samoa Islands Region	Los Angeles: 0.13 m (0.43 ft) Santa Monica: 0.15 m (0.49 ft)
October 7, 2009	Torres Islands, Vanuatu	Santa Barbara: 0.15 m (0.49 ft) Santa Monica: 0.05 m (0.16 ft)
February 27, 2010	**Offshore Maule, Chile**	**San Diego: 0.40 m (1.31 ft)** **Los Angeles: 0.42 m (1.38 ft)** **Santa Monica: 0.64 m (2.1 ft)**
March 11, 2011	**Offshore Honshu, Japan**	**San Diego: 0.63 m (2.1 ft)** **Los Angeles: 0.49 m (1.61 ft)** **Santa Monica: 0.84 m (2.76 ft)**
October 28, 2012	Haida Gwaii, Queen Charlotte Islands, British Columbia, Canada	San Diego: 0.05 m (0.16 ft) Los Angeles: 0.08 m (0.26 ft) Santa Monica: 0.08 m (0.26 ft)
February 6, 2013	Lata, Solomon Islands	La Jolla: 0.06 m (0.2 ft) Santa Monica: 0.08 m (0.26 ft)

Sources: Compiled from Lander and Lockridge (1989), McCulloch (1985), Legg et al., (2003), and http://www.ngdc.noaa.gov/

Santa Barbara Tsunami of 1812

A strong earthquake in the Santa Barbara area on December 21st, 1812 produced a tsunami that caused damage in Santa Barbara and Ventura counties and was reported along the coast of Southern California. However, the tsunami of 1812 occurred before the Newport Beach area was settled, so there are no data specific to Newport Beach for this event. The most likely source for the earthquake is a fault zone in the Santa Barbara Channel, although onshore faults east of Santa Barbara cannot be ruled out.

While some historical accounts suggest the tsunami produced a maximum one-mile runup and wave heights of 15 m (49 ft) at Gaviota, 9 to 10.5 m (29.5 – 34.5 ft) at Santa Barbara and 3.5 m (11.4 ft) at Ventura, contemporary records from the missions at Santa Barbara and Ventura do not mention tsunami runup or damage to nearby coastal communities (Lander and Lockridge, 1989). The mission records describe only a disturbed ocean and fear of tsunami, suggesting that the accounts of high waves, most of which were recorded years after the event, may have been exaggerated (Lander and Lockridge, 1989). For example, an account of "an old trader" printed in the San Francisco Bulletin 52 years after 1812, reported a 1-mile runup in Gaviota. From this account, the 15 m (49 ft) wave height reported above was derived using topographic maps.

Accounts collected by Trask (1856), 44 years after the event, report that waves damaged the lower part of the town of Santa Barbara, half a mile inland. Trask (1856) also recorded reports of a ship damaged by a tsunami wave near San Buenaventura (present day Ventura). This may be the same vessel reported by Los Angeles Star in 1857 to have been swept up a canyon at El Refugio Bay, near Gaviota. A third-hand account of tsunami damage to the mission in Ventura, located 4.5 m (14.8 ft) above sea level, is not corroborated by the mission records (Grauzinis et al., 1965). Grauzinis et al. (1965, based on data from Soloviev and Go, 1975; McCulloch, 1985; Marine Advisors, 1965; Iida et al., 1967; Wood, 1916; Heck, 1947; Toppozada et al., 1981), conclude that the most reliable historical data support a tsunami height of less than 3 m (9.8 ft) at Santa Barbara and Ventura, 3.5 m (11.4 ft) at El Refugio, and lower elsewhere in Southern California. This is roughly consistent with analysis of predicted tidal data for the region by Long (1988) who suggests a wave height of 2 m (6.6 ft) at Santa Barbara and Ventura.

Tsunami of January 1927

A magnitude 5.7 earthquake followed by several aftershocks occurred in the Imperial Valley, at the border between the United States and Mexico, on January 1, 1927. According to Montandon (1928), sea waves in San Pedro destroyed a seawall or embankment causing about three million dollars in damage (Lander and Lockridge, 1989). However, since the Imperial Valley is far from the coast, and the earthquake was moderate in size, it is doubtful that these two events are related, unless the earthquake triggered a submarine landslide.

Possible Tsunami of 1934

On August 21, 1934 large destructive waves were reported along the coast of Southern California from Malibu to Laguna Beach. The true source of the waves is not known, however several causative events have been suggested. Although official records show no large earthquakes in the area on the day of the waves, a small, magnitude 3 tremor was reported in the Balboa region before the waves struck. Submarine landsliding, volcanic activity, and unusual meteorological conditions (rogue waves?) have also been suggested as possible explanations for the waves. A runup of 270 m (886 ft) inland, 3 m (9.8 ft) above mean high tide level was recorded at Newport Beach, which flooded part of the City to a depth of one meter (3.3 ft). Four people were injured near the channel entrance to Newport Bay, at the western pier. Many houses were destroyed, including a two-story home in Balboa that was detached from its foundation. Part of the pavement on Balboa Peninsula was washed away, temporarily isolating the residents of this area from the mainland. Thousands of tons of debris were tossed onshore. The waves also flooded a moorage in Balboa Island and collapsed part of the breakwater in Long Beach (Lander and Lockridge, 1989).

Aleutian Island Tsunami of 1957

A magnitude 8.3 earthquake in the Aleutian Islands on March 9, 1957 generated a small tsunami in the San Diego area that damaged two ships in San Diego Harbor and caused minor damage at La Jolla (McMulloch, 1985; Iida et al., 1967; Salsman, 1959; Joy, 1968). A wave height of up to one meter (3.3 ft) was reported at Shelter Island, off the San Diego coast, although the tide gauge there recorded only a 0.2 m (0.7 ft) wave. No reports of damage were recorded in the City of Newport Beach.

Chilean Tsunami of 1960

On May 22, 1960, a moment magnitude 9.4 earthquake off the coast of Chile produced a tsunami that damaged coastal communities in Southern California between Santa Barbara and San Diego. A wave height of 1.4 m (4.6 ft) was recorded in Santa Monica and the tidal gauge in San Diego was carried away by the tsunami waves (Lander and Lockridge, 1989). Significant damage was recorded in the Los Angeles and Long Beach Harbors, where 30 small craft were sunk and over 300 were set adrift. Over 340 boat slips, valued at $300,000, were also damaged in the area. At Santa Monica, eight small boats were swept away and a runup of 91 m (300 ft) flooded a parking lot along the Pacific Coast Highway. Damage of $20,000 was reported in the Santa Barbara area. At San Diego, two passenger ferries were knocked off course by the waves; the first ferry was pushed against a dock in Coronado, destroying 80 m (260 ft) of the dock, and the second was rammed into a flotilla of anchored destroyers. The waves also rammed a 100-ton dredge into the Mission Bay Bridge, knocking out a 21 m (70 ft) section and sinking a barge at Seaforth Landing (Lander and Lockridge, 1989; Iida et al., 1967; Talley and Cloud, 1962; Joy, 1968).

Good Friday Earthquake Tsunami of 1964

On March 28, 1964 a moment magnitude 9.2 earthquake in the Gulf of Alaska produced a very large and damaging tsunami in the West Coast. The tsunami killed 16 people in northern California and Oregon and caused $8,000,000 in damage in California. Although damage was primarily focused in coastal areas north of San Francisco, Southern California experienced hundreds of thousands of dollars in losses. A wave height of 1 m (3.3 ft) was recorded in Santa Monica. In Los Angeles Harbor, the wave damaged six small-boat slips, pilings, and the Union Oil Company fuel dock. It also scoured the harbor sides, causing, all tolled, $175,000 to $275,000 in damage. The tsunami also destroyed eight docks in the Long Beach Harbor at a loss of $100,000 (Spaeth and Berkman, 1972). Minor damage was also reported elsewhere along the Southern California coast.

Chilean Tsunami of February 2010

The magnitude 8.8 earthquake off the coast of Chile caused a tsunami that arrived in southern California approximately 5 hours after the earthquake, with highest wave amplitudes reported one to six hours after the first wave arrival. The highest tide gauge readings were reported in Santa Barbara, Pismo Beach and San Diego Bay. Minor damage to docks and marine infrastructure was reported in Marina del Rey, Two Harbors (Catalina), Los Angeles, and Oceanside. Moderate damage to docks, concrete piers and boats was reported in North Shelter Island (San Diego Bay). No damage was reported in Newport Beach, Huntington Beach, Seal Beach, Long Beach, and La Jolla (Wilson et al., 2011).

Tohoku-oki Tsunami of March 2011

The magnitude 9.0 earthquake off the eastern coast of Japan generated a tsunami train that impacted the California coast, with tsunami activity lasting as much as 24 hours after the first wave arrived. Although most of the damage reported occurred in Northern California, especially at Crescent City and Santa Cruz, minor to moderate damage was reported in some harbors in Southern California. Specifically, the tsunami waves destroyed a dock and damaged 13 boats in Mission Bay, a boat was sunk and a dock was damaged in south Shelter Island (San Diego), a pylon was damaged when hit by a boat in Dana Point, a boat was pulled off its moorings in Huntington Beach, and minor damage to docks and boats was reported in Los Angeles and Long Beach. No damage was reported in Newport Beach, Sunset Beach, La Jolla, or Oceanside. The damage in Mission Bay was estimated at $136 thousand (Wilson et al., 2011).

Seismically Induced Inundation

Dam Failure Flooding

Seismically induced inundation refers to flooding that results when water retention structures (such as dams) fail due to an earthquake. Failure of these structures can also result from other causes, such as overtopping, foundation problems, or construction errors. Statutes governing dam safety are defined in Division 3 of the California State Water Code (California Department of Water

Resources, 1986). These statutes empower the California Division of Dam Safety to monitor the structural safety of dams that are greater than 25 feet in dam height or have more than 50 acre-feet in storage capacity.

Dams under State jurisdiction are required to have inundation maps that show the potential flood limits in the remote, yet disastrous possibility, that a dam is catastrophically breached. Inundation maps are prepared by dam owners to help with contingency planning; these inundation maps in no way reflect the structural integrity or safety of the dam in question. Because dam failure can have severe consequences, FEMA requires that all dam owners develop Emergency Action Plans (EAP) for warning, evacuation, and post-flood actions. Although there may be coordination with county officials in the development of the EAP, the responsibility for developing potential flood inundation maps and facilitation of emergency response is the responsibility of the dam owner. Dam owners are also required to prepare and submit emergency response plans to the State Office of Emergency Services, the lead State agency for the State dam inundation-mapping program. Cities and counties are required by State law to have in place emergency procedures for the evacuation and control of populated areas within the limits of dam inundation. In addition, legislation requires real estate disclosure upon sale or transfer of properties in the inundation area (AB 1195 Chapter 65, June 9, 1998; Natural Hazard Disclosure Statement).

There have been a total of 45 dam failures in California since the 19th century. The most significant dam failures in Southern California are listed in Table 7-6, and the two most significant dam failures, St. Francis Dam in 1928 and the Baldwin Hills Dam in 1963, are described further below.

Table 7-6: Dam Failures in Southern California

Dam Name	Location	Year	Failure Mechanism
Sheffield	Santa Barbara	1925	Earthquake slide
Puddingstone	Pomona	1926	Overtopping during construction
Lake Hemet	Palm Springs	1927	Overtopping
Saint Francis	San Francisquito Canyon	1928	Sudden failure at full capacity through foundation, more than 400 deaths.
Cogswell	Monrovia	1934	Breaching of concrete cover
Baldwin Hills	Los Angeles	1963	Leak through embankment turned into washout, 3 deaths.

St. Francis Dam, completed in 1926 in the San Francisquito Canyon near Saugus, was 180 feet high and 600 feet long. Its failure was a scandal that resulted in the almost complete destruction of the reputation of its builder, William Mulholland. Mulholland was an immigrant from Ireland who rose up through the ranks of the Los Angeles City Water Department to the position of chief engineer. It was he who proposed, designed, and supervised the construction of the Los Angeles Aqueduct, which brought water from the Owens Valley to Los Angeles.

St. Francis dam gave way on March 12, 1928, three minutes before midnight. Its waters swept through the Santa Clara Valley toward the Pacific Ocean, about 54 miles away. Sixty-five miles of valley were devastated before the water finally made its way into the ocean between Oxnard and Ventura. At its peak, the wall of water was said to be 78 feet high; by the time it hit Santa Paula, 42 miles south of the dam, the water was estimated to be 25 feet deep. Almost everything in its path was destroyed: livestock, structures, railways, bridges, and orchards. By the time it was over, parts of Ventura County lay under 70 feet of mud and debris. Over 400 people were killed and damage estimates topped $20 million.

The Baldwin Hills dam, an earthen dam that created a 19-acre reservoir to supply drinking water to West Los Angeles residents, failed on December 14, 1963 at 3:38 in the afternoon. This is one of the first disaster events documented in a live helicopter broadcast – the live telecast of the collapse from a KTLA-TV helicopter is considered the precursor to airborne news coverage that is now routine everywhere. As a pencil-thin crack widened (see Figure 7-9) to a 75-foot gash, 292 million gallons surged out. "The Baldwin Hills Dam collapsed with the fury of a thousand cloudbursts, sending a 50-foot wall of water down Cloverdale Avenue and slamming into homes and cars . . . Five people were killed. Sixty-five hillside houses were ripped apart, and 210 homes and apartments were damaged." The flood swept northward in a V-shaped path roughly bounded by La Brea Avenue and Jefferson and La Cienega boulevards.

It took 77 minutes for the impounded reservoir to empty, but it took a generation for the neighborhood below to recover, illustrating the severe, long-term impact of these disasters. Furthermore, failure of this tank foreshadowed the end of urban-area earthen dams as a major element of the Department of Water and Power's water storage system. It also prompted a tightening of Division of Safety of Dams control over reservoirs throughout the State.

Figure 7-9: Initial Failure of Baldwin Hills Dam. Dark spot in lower right-hand quadrant shows the beginning of the break in the dam.

Flooding Due to Failure of Above-Ground Water Storage Tanks

Seismically induced inundation can also occur if strong ground shaking causes structural damage to above-ground water tanks. If a tank is not adequately braced and baffled, sloshing water can lift a water tank off its foundation, splitting the shell, damaging the roof, and bulging the bottom of the tank (elephants foot) (EERI, 1992). Movement can also shear off the pipes leading to the tank, releasing water through the broken pipes. These types of damage occurred during Southern

California's 1992 Landers, 1992 Big Bear, and 1994 Northridge earthquakes. The Northridge earthquake alone rendered about 40 steel tanks non-functional (EERI, 1995), including a tank in the Santa Clarita area that failed and inundated several houses below. As a result of lessons learned from recent earthquakes, new standards for design of steel water tanks were adopted in 1994 (Lund, 1994). The new tank design includes flexible joints at the inlet/outlet connections to accommodate movement in any direction. All of Newport Beach's water steel tanks have been retroffited with flexible expansion joints to allow for movement during earthquakes.

Water lost from tanks during an earthquake can significantly reduce the water resources available to suppress earthquake-induced fires. Damaged tanks and water mains can also limit the amount of water available to residents. Furthermore, groundwater wells can be damaged during an earthquake, also limiting the water available to the community after an earthquake. Therefore, it is of paramount importance that the water storage tanks in the area retain their structural integrity during an earthquake, so water demands after an earthquake can be met. In addition to evaluating and retrofitting to meet current standards, this also requires that the tanks be kept at near full capacity as much as practical.

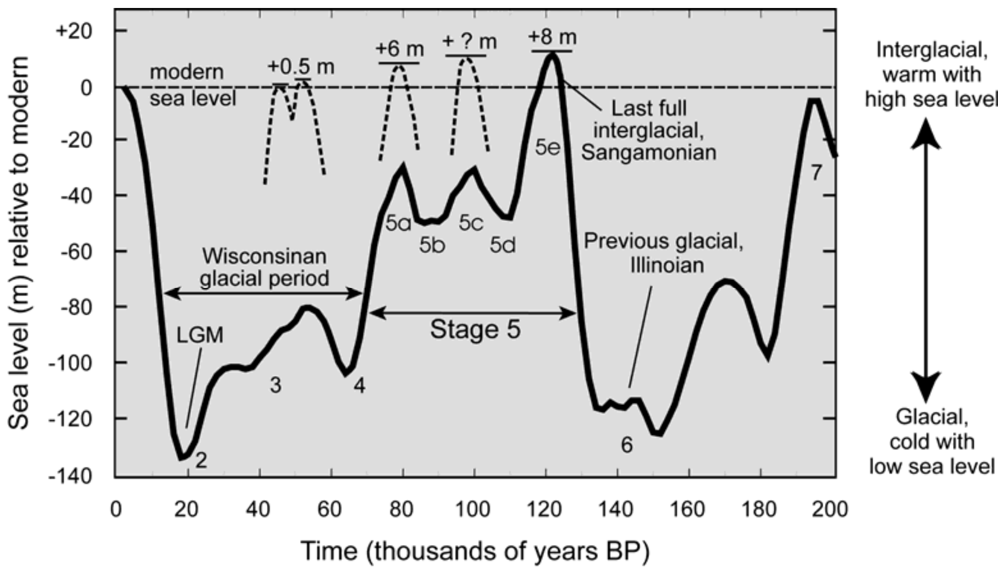
Flooding Due to Sea Level Rise

Sea Level Change

The geological record shows that the level of the oceans fluctuates with changes in global temperatures (see Figure 7-10 showing the changes in sea level over the last about two hundred thousand years). During the previous last major interglacial period (approximately 120,000 years ago), temperatures were about 2°F (1°C) warmer that today and sea level was approximately 20 to 26 feet (6 to 8 meters) higher than today (Mercer, 1970). During the last ice age (the last glacial maxima – LGM, approximately 20,000 years ago, see Figure 7-10), when global temperatures were 9°F (5°C) lower than today, much of the ocean's water was tied up in glaciers, sea level was as much as 430 feet (130 meters) lower than today (Oldale, 1985; Lajoie et al., 1991), and the California coast was 5 to 15 miles (8 to 25 km) farther offshore than its present position (Department of Boating and Waterways and State Coastal Conservancy, 2002). The last ice age ended approximately 18,000 years ago, and since then the world has been experiencing global warming such that many of the ice caps have melted, most of the continental-sized glaciers have retreated, and sea level has risen. Between about 18,000 and 5,000 years ago, the rise in sea level occurred rapidly, at an average rate of nearly 0.4 in (1 cm) a year. In the past about 5,000 years and up to about the end of the 19th century, sea level essentially stayed the same. Then, in the last century, sea level rise picked up speed again such that on average, global sea level between the years 1900 and 2000 rose 7 inches (see Figure 7-11). Higher rates of sea level rise are estimated in the next few decades, as shown on Figure 7-11.

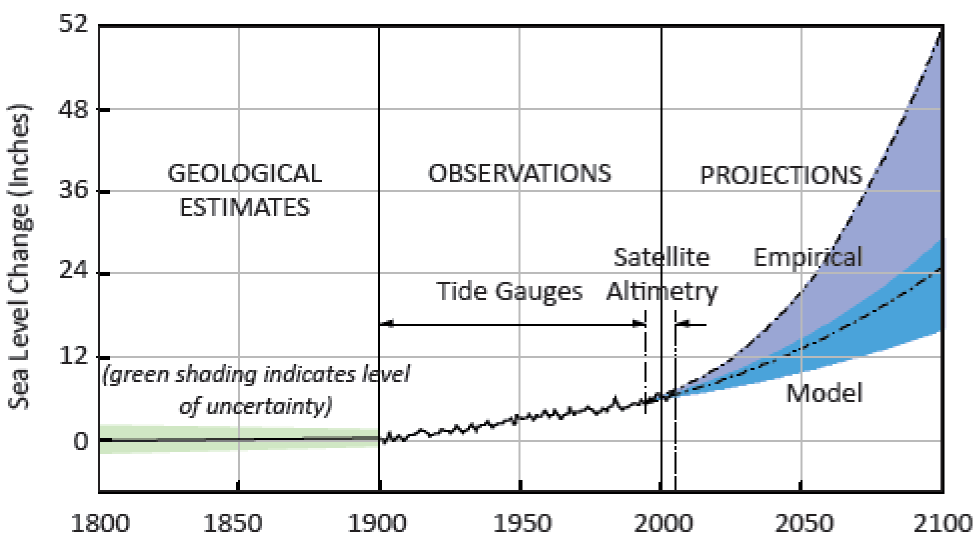
The scientific consensus is that global climate is changing, with an increase in sea water temperatures, melting of the last remaining glaciers, and an increase in more severe storms. Although the rise in sea level will be somewhat gradual, coastal communities are already experiencing the effects of global climate change in the form of more frequent storm flooding, and increased cliff, bluff and shoreline erosion. These conditions are already impacting infrastructure (including transportation routes, harbors, wastewater treatment plants, and storm water systems), and residential and commercial property.

Figure 7-10: Worldwide Sea Level Curve for the Past Two Hundred Thousand Years Using Current Sea Level as the Reference Point



From Martinson et al., 1987
(BP = before present; LGM = Last Glacial Maxima; sea level in meters)

Figure 7-11: Sea Level in Recent Times and Predictions of Future Sea Level



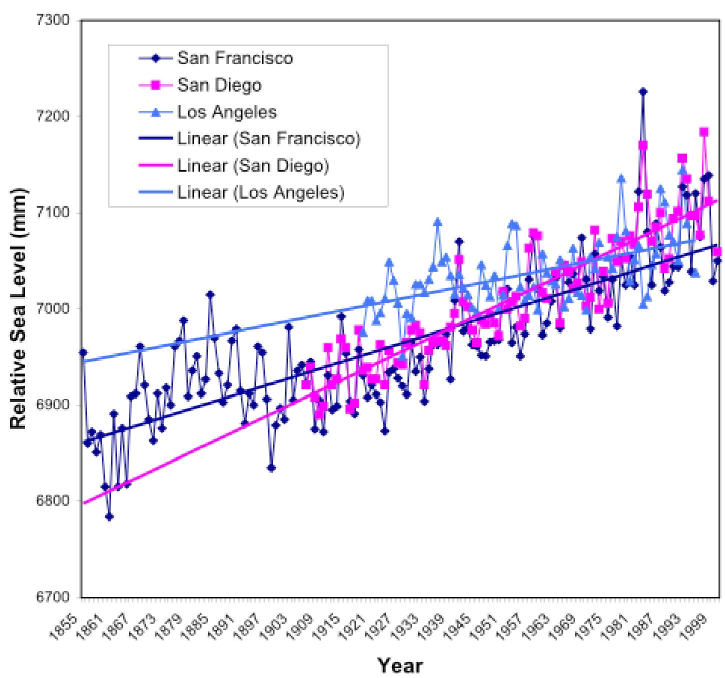
From Russell and Griggs (2012) who updated data from Shum and Kuo (2011)

When discussing shorter periods of time, one must distinguish worldwide (eustatic) sea level rise from relative sea level rise, which includes land subsidence or uplift. Also, as ocean temperatures rise, sea water expands, raising sea level even further. Although climate impacts sea level worldwide, the rate of sea level rise relative to a particular coast has more practical importance and is all that current monitoring stations can measure. Because, due to plate tectonics and other geological reasons, some coastal areas are sinking while others are rising, relative sea level rise in the United

States varies from more than 3 feet (1 meter) per century in Louisiana and parts of California and Texas, to 1 foot (30 centimeters) per century along most of the Atlantic and Gulf Coasts, to a slight drop in much of the Pacific Northwest (Titus et al., 1991; Knuuti, 2002). Large variations can also occur locally. For example, in San Francisco, the Presidio gauge near the entrance to the Golden Gate has measured a relative sea level rise of 0.06 inches/yr (1.41 mm/yr) in the past nearly 150 years. Across the bay, however, the 60-year-long gauge record at Alameda shows a relative mean sea level rise of only 0.035 inch/yr (0.89 mm/yr). Closer to home, in Los Angeles, the relative mean sea level trend for 87 years of record is 0.033 inch/yr (0.83 mm/yr), while in San Diego the 104-year-long record shows a linear trend in relative sea level rise of 0.081 inch/yr (2.06 mm/yr). In Newport Beach, 40 years of data (between 1955 and 1995) indicate an average sea level rise of 0.087 inch/yr (2.22 mm/yr), one of the fastest rates in the southern California region (Russell and Griggs, 2012).

For a comparison of the relative sea level rise measured at the San Francisco, Los Angeles, and San Diego gauges, refer to Figure 7-12. This figure briefly shows that quantifying sea level changes worldwide is not a simple task.

Figure 7-12: Historical Relative Sea Level Rise at Three Locations along the Pacific Coast of the United States (San Francisco, Los Angeles and San Diego)

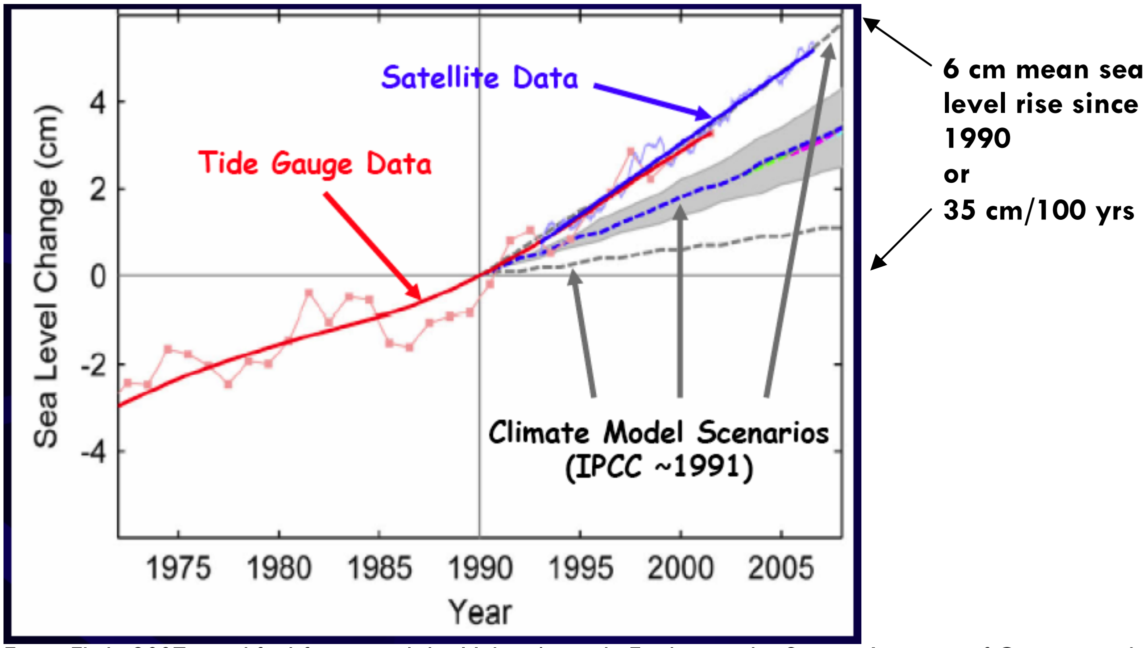


Linear Trends at each Location are shown by the Straight Lines

Source: Based on data obtained at http://www.nbi.ac.uk/psmsl/psmsl_individual_stations.html

After accounting for these local effects, worldwide sea level has risen 10 to 25 cm (4 to 10 inches) (Peltier and Tushingham, 1989), much of which has been attributed to global warming (Meier, 1984). Since 1990, sea level has risen approximately 6 cm, which calculates to about 35 cm per century (Flick, 2007), a much faster rate than the models predicted (see Figure 7-13).

Figure 7-13: Sea Level Rise – Observations Against Predictions



From Flick, 2007; modified from work by Helen Amanda Fricker at the Scripps Institute of Oceanography, San Diego.
IPCC = Intergovernmental Panel on Climate Change

Effects of Sea Level Rise

Although sea level rise by itself does not cause substantial changes in the landform, several processes associated with sea level rise can have dramatic effects on our environment. For example, a significant rise in sea level will inundate coastal wetlands and lowlands, and the increased surges and swells associated with this rise in sea level will accelerate coastal erosion and exacerbate coastal flooding, thereby threatening local structures and habitat. The combined effects of sea level rise and the high tides and large waves brought on by storms, especially during El Niño events, will, in the short-term, result in increased flooding of low-lying areas, and accelerated erosion of beaches and sea cliffs. Other related processes include higher water tables, increased sea-water intrusion into fresh water aquifers, and increased salinity of rivers, bays, and aquifers (Titus et al., 1991). The warmer climate may also result in a much higher probability of extremely warm years with increased precipitation in some areas, and drought in other areas. It is clear that global changes in climate are occurring, but the local impacts are still being determined.

Hazard Assessment

Hazard Identification – Flood Hazard Mapping in Newport Beach

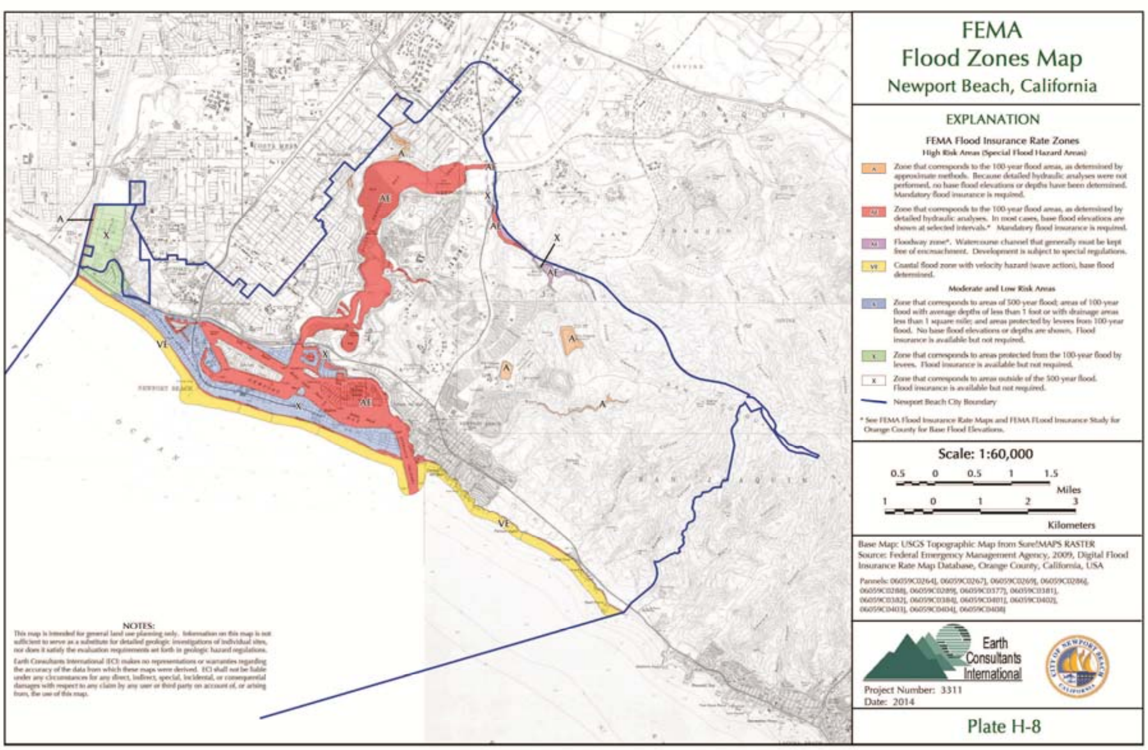
Hazard identification is the first phase of flood-hazard assessment. Identification is the process of estimating: 1) the geographic extent of the floodplain (i.e., the area at risk from flooding); 2) the intensity of the flooding that can be expected in specific areas of the floodplain; and 3) the probability of occurrence of flood events. This process usually results in the creation of a floodplain map. Floodplain maps provide detailed information that can assist jurisdictions in making policies and land-use decisions.

Inundation Due to Storm Flooding

The City of Newport Beach has participated in the National Flood Insurance Program since September 1, 1978 *(City ID No. – 060227)*. The extent of flooding on the Santa Ana River, San Diego Creek, and a few smaller streams within Newport Beach has been analyzed through Flood Insurance Studies, with the bulk of that work conducted by the U.S. Geological Survey in 1977. The potential flood zones in the City mapped by FEMA are presented in Flood Insurance Rate Maps (FIRMs). The most recent FIRM map for the City dates from December 3, 2009, and incorporates several letters of map revision and jurisdictional changes. Map 7-6 shows the FIRM inundation limits for both the 100-year and 500-year flood events. Please note that the 500-year flood zone includes the 100-year flood zone.

The 100-year flood (red and orange zones in Map 7-6) is anticipated to inundate the area from Beach Boulevard in Huntington Beach, to Fairview Park Bluffs in Costa Mesa, a narrow strip of undeveloped land at the base of the bluffs in Newport Beach, and the entire coastline. Both the 100- and 500-year floods will be contained within the channel of San Diego Creek, but Balboa Island will be under water and property along the margins of Newport Bay will be inundated. The 100-year flood zone also includes the central reaches of Buck Canyon, Bonita Canyon, and the San Joaquin and Big Canyon Reservoirs. Most of West Newport is protected from the 100-year flood by levees (green area on Map 7-6 and Plate H-8). The areas shown in blue on Map 7-6 are located within the 500-year flood zone. This includes all of Balboa Peninsula, and the areas next to the Newport Bay south of Coast Highway.

Map 7-6: FEMA Flood Zones Map for Newport Beach, California
(For a larger version of this map, refer to Plate H-8 in Appendix H)



Although, as indicated above, the FIRM map that covers Newport Beach is relatively recent, the bulk of the analyses supporting the map were made in 1977, and since then, there has been substantial development in the hills of Newport Beach, with the potential to increase runoff into the City's storm drains and flood-conveyance system. To address these issues, detailed hydrologic studies to study the impact of these developments on Coast Highway and adjacent areas were conducted as part of Phase IV-2 of the Newport Coast Planned Community (formerly called the Irvine Coast Planned Community prior to annexation to the City). This community encompasses much of the land in the San Joaquin Hills, including the Muddy Canyon and Los Trancos Canyon watersheds.

Los Trancos Canyon is one of two predominantly undeveloped watersheds in Newport Beach. The headwaters originate near Signal Peak (at an elevation of 1,150 feet above sea level) and drain an 1,180-acre watershed. Prior to development near the mouth of Los Trancos Canyon, The Keith Companies (1987; as reported in LSA, 1998) calculated a 100-year discharge of 1,952 cfs. After development, the modeled 100-year discharge increased to 2,377 cfs, most likely due to increased runoff associated with impervious surfaces (John M. Tettemer and Associates, 1998). However, according to the cited reports, the construction of detention basins should decrease the 100-year discharge to 1,683 cfs at Coast Highway. A single 9-foot by 10-foot arch culvert drains these flows beneath Coast Highway. Widening of Coast Highway necessitated extending this culvert, with a resulting decrease in conveyance through the culvert and a higher ponded water surface upstream of Coast Highway. This condition likely increases the potential for flooding at the Coast Highway crossing.

Muddy Canyon is the other predominantly undeveloped watershed in Newport Beach. The Keith Companies (1987, as reported in LSA, 1998) calculated a pre-development 100-year discharge of 1,470 cfs for the 990-acre Muddy Canyon watershed. After development, the 100-year discharge was estimated to increase to 1,908 cfs (John M. Tettemer and Associates, 1998). However, like in Los Trancos Canyon, detention projects are expected to reduce the post-development 100-year discharge to only 1,008 cfs. A single 8-foot by 6-foot arch culvert drains floodwaters beneath Coast Highway, but currently conveys less than the 100-year discharge. The post-development 100-year water surface behind the culvert is about 2 feet higher than the existing 100-year conditions. However, according to John M. Tettemer and Associates (1998), the culvert inlet was to be modified so all of the 100-year discharge would be conveyed for the post-development conditions.

As discussed previously, urban street flooding tends to occur in the City of Newport Beach when heavy rainfall coincides with high tides. During these instances, the low-lying streets in Newport Beach often become inundated. For example, when tides reach ~6.5 feet and heavy rain is falling, the streets around the Marcus and Finley Tracts on Balboa Peninsula flood. This condition also occurs along the lowest lying areas of Balboa Island. An 8.3-foot high tide would flood all of Newport Coast. To deal with these issues, the City of Newport Beach operates a total of 86 tide valves. These valves are usually closed to keep high tides from flooding the streets on Balboa Island and on the Peninsula. During rainstorms, urban runoff is in effect dammed by these tide valves. To mitigate this problem, the City pumps into the harbor and bays the urban runoff that has ponded at the street ends. This system has proven effective in minimizing the impacts of urban street flooding.

Inundation Due to Tsunamis and Rogue Waves

Because of the substantial increase in population in the last century and extensive development along the world's coastlines, a large percentage of the Earth's inhabitants live near the ocean. As a result, the risk of loss of life and property damage due to tsunamis has increased substantially. In fact, worldwide, tsunamis have been responsible for between 250,00 and 375,000 human deaths in the past decade alone, with between 225,000 and 350,00 of those attributed to the December 26, 2004 tsunami off of the west coast of Sumatra, and nearly another 20,000 to the March 11, 2011 tsunami off the east coast of Japan (the total number of fatalities caused by the Sumatra tsunami is, as of the writing of this report, still unclear, with different figures provided by different sources).

McCarthy et al. (1993) reviewed the historical tsunami record for California and suggested that the tsunami hazard in the Southern California region, from the Palos Verdes Peninsula south to San Diego, is moderate. However, the Southern California historical tsunami record is very short and likely underestimates the true hazard. Given that the recurrence interval for many of the faults in the world is in the order of hundreds to thousands of years, it is possible that Southern California has been impacted by teletsunamis for which we have no record. Also significant is the fact that there are several active faults immediately offshore of the Southern California area, and any of these could generate a future earthquake that could have a tsunami associated with it. Finally, several submarine landslides and landslide-susceptible areas have been mapped offshore, within 2 to 8.7 miles (3.5 to 14 km) of the coastline (Field and Edwards, 1980; McCulloch, 1985; Clarke et al., 1985).

Synolakis et al. (1997) reviewed the McCarthy et al. (1993) study and other data, and concluded that not only do early, pre-1980 methods give tsunami runup results that are more than 50 percent lower than what more current inundation models predict, but that there is a need to model near-shore tsunami events. For the Orange County coastline particularly, near-shore tsunamis should be considered worst-case scenarios, as these have the potential to cause high runups that would impact the coastline with almost no warning. In their 2005 report on tsunami threats, the California Seismic Safety Commission indicates that teletsunamis and locally generated tsunamis pose a significant threat to life and property in California.

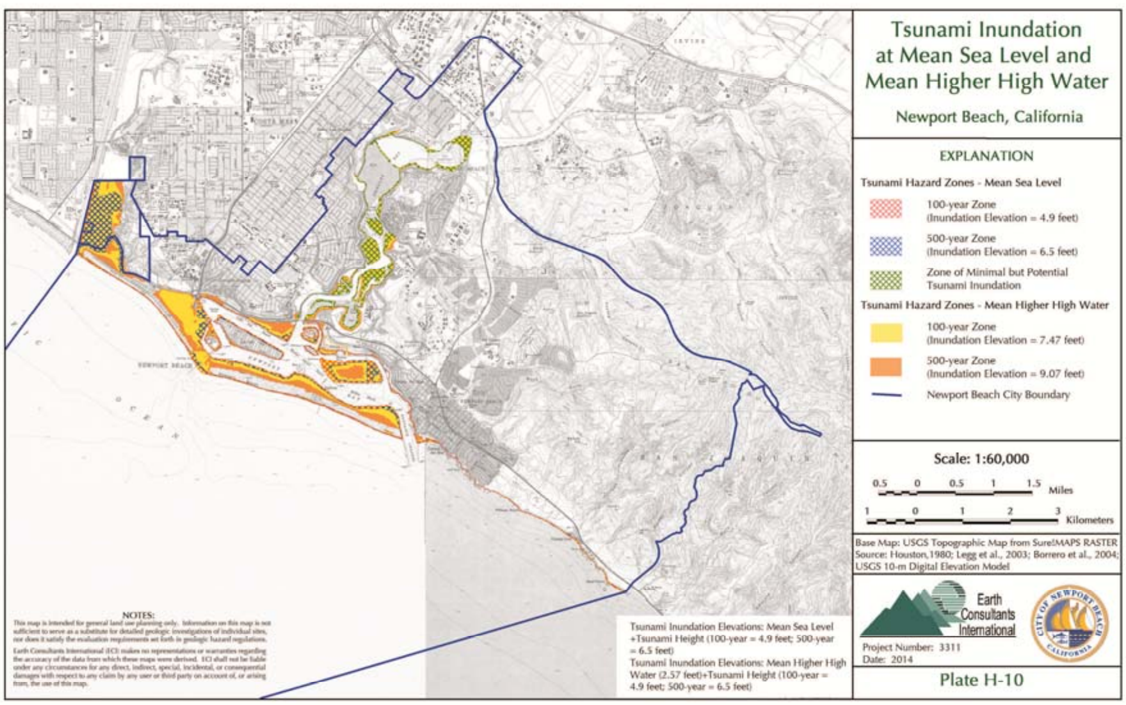
Having recognized the potential hazard, the next step was to quantify it so it can be managed appropriately. Although the record of tsunamis impacting the California coast goes back only to 1812, there are sufficient data from which mathematical models of tsunami runup for the California coast can be developed. Houston and Garcia looked at the worldwide, long-term historical data, and combined it with mathematical models to estimate the predicted, distantly generated, 100-year and 500-year probability tsunami runup elevations for the west coast of the United States (Garcia and Houston, 1975; Houston and Garcia, 1974; 1978; Houston et al., 1975; Houston, 1980; as presented in McCulloch, 1985).

These predictions are used by the Federal Insurance Administration to calculate flood-insurance rates, thus the 100- and 500-year terms risk levels selected, similar to storm flooding. As with flooding, the 100- and 500-year designations do not mean that these tsunamis occur only once every 100 or 500 years, but rather, these terms describe the tsunami that has a 1 percent (for 100-year) or 0.2 percent (for 500-year) probability of occurring in any one year. The 100-year and 500-year tsunami runup elevations are thought to have the potential to cause significant damage to harbors and upland areas, while smaller 50-year events may cause damage to boats and harbor facilities, but the onshore damage will be restricted to very low-lying areas. Smaller than 50-year tsunamis may still cause minor damage to unprotected boats and harbor facilities (CDMG, 1976). The 100-year (R_{100}) and 500-year (R_{500}) teletsunami runup heights predicted for Newport Beach are 1.49 and 1.98 m (4.9 and 6.5 ft), respectively (Houston, 1980, based on Figure 208 in McCulloch, 1985).

The predicted tsunami runup heights by Houston (1980) were used to prepare maps showing tsunami inundation zones for Newport Beach that were included in the City's 2006 Safety Element of the General Plan and the City's 2008 Disaster Mitigation Plan (see Map 7-7 below). For various reasons, these values are to be used only as a guide to quantify the risk of distantly generated tsunamis on the California coastline. Houston (1980) did not have the technology available to quantify the effect that estuaries, the offshore zone where water is 16 to 33 feet (5 to 10 meters) deep, and the shoreline have on tsunami runup (C. Synolakis, personal communication, 2002). Furthermore, Houston's (1980) predicted heights were based on mean sea level elevation data, and thus do not show the maximum credible heights that are possible if a tsunami coincides with peak high tide, or with storm-induced high water. To account for this, several scenarios were prepared as part of the Safety Element of the General Plan for Newport Beach to show the estimated inundation areas expected in the City under different sea level conditions. These scenarios are simple, linear, first-order assessments of inundation of all land areas at an elevation equal to or below the elevation of the water column calculated for each scenario, without taking into consideration the shallow bathymetry and near-shore topography, which are known to have a significant impact on tsunami inundation.

A tsunami inundation map assuming that the sea level at the time of impact is at mean sea level and mean higher high water is shown in Map 7-7, below. Mean sea level **(**MSL) is defined as the average height of the ocean surface for all tide stages, measured over a 19-year period based on hourly height observations made on an open coast, or in adjacent waters having free access to the sea (Bates and Jackson, 1987). Mean sea level is adopted as the *datum plane* or *zero elevation* for a local or regional area. In March 2005, the City of Newport Beach adopted the North American Vertical Datum (NAVD) as the official datum plane of the City (City Ordinance No. 2005-4; Code Amendment 2005-047). All other water levels and topographic elevation points in the City are now measured relative to this datum. Prior to 2005, the City used the NGVD29 (National Geodetic Vertical Datum) system, a system that has fallen in disuse; the NAVD88 system in this area is on average 2.37 feet higher than the NGVD29 datum.

Map 7-7: Tsunami Inundation Map at Mean Sea Level and Mean Higher High Water Level (for a larger version of this map, refer to Plate H-10)



Please note that Map 7-7, which shows the predicted tsunami inundation areas for Newport Beach for the predicted 100- and 500-year tsunami runup heights (4.9 and 6.5 feet, respectively) superimposed on mean sea level and mean higher high water, are based on the NGVD29 datum. This map shows that if a tsunami is generated by an earthquake on one of the faults offshore the

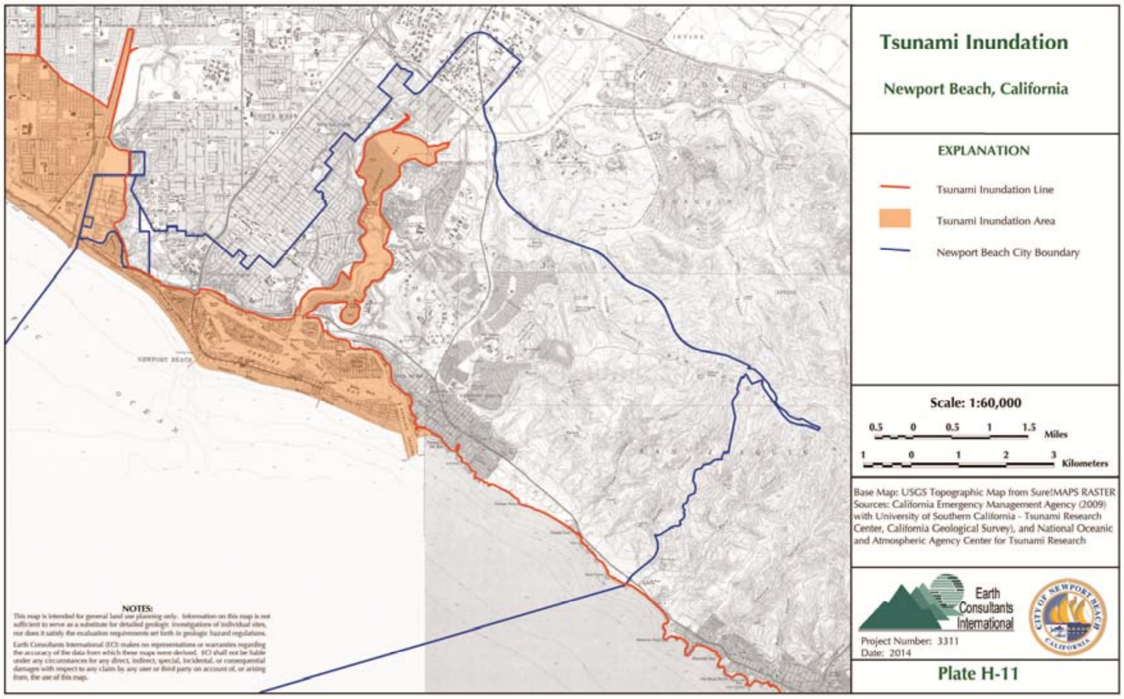
Southern California coast, Newport Bay and most of the harbor have the potential of being inundated. Specifically, if the tsunami occurs during mean sea level, low-lying areas adjacent to the coast, properties near the water in Balboa Island, and Lido and Linda Isles, and all moored boats are expected to be impacted by the wave runup. If the tsunami hits during mean higher high water, most of the harbor area, including the inland, developed portion of the Balboa Peninsula, Balboa Island, and Upper Newport Bay could be inundated. Near-shore sections of Lido Isle and Linda Isle would also be impacted, and Lido Isle would be cut off from the mainland due to flooding along Newport Boulevard and 32nd Street. Mean High Water (MHW) is referred to as the "average height of all the high waters recorded at a given place over a 19-year period or computed equivalent period" (Bates and Jackson, 1987). The MHW can often be recognized by the upper line of debris on the beach. For Newport Beach, the calculated MHW is 0.78 m (2.57 ft; using the NGVD29 datum). The water level in Upper Newport Bay is anticipated to rise some, but the data available are insufficient to quantify the hazard in this area.

Since the tsunami inundation map described above was prepared, a group of tsunami modelers, geologic hazard specialists and emergency planners have developed maximum tsunami inundation maps for a large section of coastal California. The maps were created using the Method of Splitting Tsunami (MOST) modeling program (Titov and Gonzalez, 1997; Titov and Synolakis, 1998) by researchers at the Tsunami Research Center at the University of Southern California. Draft inundation maps prepared using this software were checked in the field with emergency planners from local jurisdictions, and post-field draft tsunami maps were then sent to the local lead agencies for review and comments. Once the recommended changes were considered and implemented, as appropriate, the final inundation maps were sent to the local lead agencies and were also posted in state tsunami program websites. The final maps are available from the California Geological Survey website, via a map file (kmz format) that can be read in Google Maps (http://www.conservation.ca.gov/cgs/geologic_hazards/Tsunami/Inundation_Maps/Pages/Index.aspx). These maps show the worst-case scenario based on an analysis of both local and distant tsunami sources and their impact on 33 coastal populated areas along the California coastline (Wilson et al., 2008). The tsunami inundation map for the Newport Beach quadrangle issued by the California Emergency Management Agency in cooperation with the University of Southern California Center for Tsunami Research, and the California Geological Survey, dates from March 15, 2009 (see Map 7-8). Sources used to develop this map include surface-rupturing earthquakes on the Catalina and Newport-Inglewood faults, submarine landslides off the Palos Verdes peninsula, and earthquakes like the 1960 Chile, 1964 Alaska, and in the Central Aleutians and North Chile subduction zones.

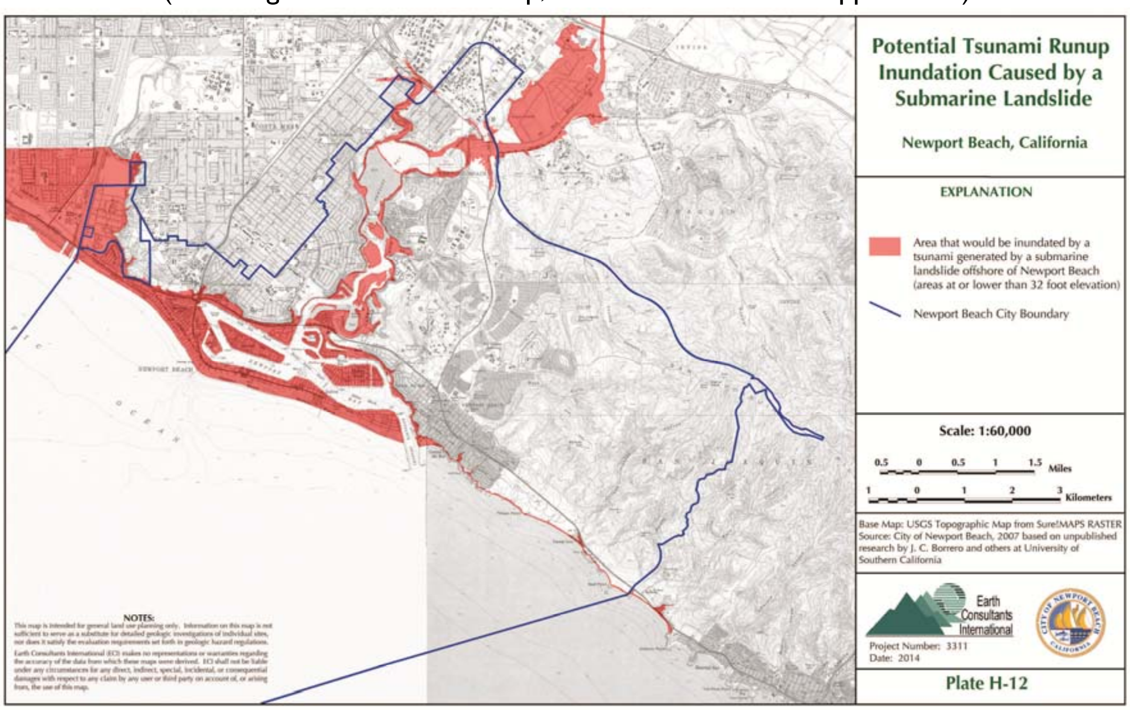
The local sources described in the paragraph above are based on collaborative work between the USC research group and Dr. Mark Legg (Legg et al., 2003), who conducted an evaluation of the tsunami risk to coastal Southern California cities by modeling potential locally generated tsunamis caused by either offshore faulting (such as on the Catalina fault) or submarine landsliding. These assessments were made after their initial models indicated that locally generated tsunamis are a concern: earthquakes in the Santa Barbara Channel could generate a 2 m (6.6 ft) runup, while an earthquake-induced submarine landslide could generate a runup of as much as 20 m (66 ft) (Borrero et al., 2001). An earthquake on the San Clemente fault could generate run-up of between 1.5 and 2.0 meters (4.9 and 6.6 ft) in the Newport Beach area.

The concern with these local tsunami sources is that travel time between the local source of an earthquake and the arrival of the first waves along the coastline is estimated at 10 to 20 minutes, which does not allow much time for broadcasting of warnings and evacuation, but the strong shaking should. Several wave crests are likely, with the second and third waves likely to be higher than the first. If some of these wave crests strike the coastline during high tide, there is a potential for even more severe destruction (Legg et al., 2003).

Map 7-8: Tsunami Inundation Map for the Newport Beach Area Prepared and Issued in 2009 by the California Emergency Management Agency, Earthquake and Tsunami Program (refer to text for additional information; for larger version of this map, refer to Plate H-11 in Appendix H)



Map 7-9: Tsunami Runup Inundation Caused by a Potential Submarine Landslide
(for a larger version of this map, refer to Plate H-12 in Appendix H)



If a locally generated tsunami hits during high tide, an even larger portion of Newport Beach would be inundated. The impacted area would be similar to the area shown on Map 7-9. Map 7-9 shows the area likely to be inundated if a submarine landslide-generated tsunami occurs. Dr. Jose Borrero and his colleagues at the University of Southern California have estimated that a potential submarine landslide anywhere along the steep Southern California offshore escarpment could generate a tsunami with a 30 to 33 foot runup in Orange County. The City of Newport Beach opted to use a 32-foot runup elevation for their tsunami evacuation plan; this is the map presented in Map 7-9 and Plate H-11. The low-lying coastal areas of Orange County, including most of West Newport and the low areas surrounding the bay, are expected to be impacted by such a tsunami. Additional modeling based on more detailed bathymetric data is needed to better quantify the potential impact to the region, but the preliminary analyses indicate that near-source tsunamis pose a low probability but high risk to the extensively developed coastal areas of Southern California.

Inundation Due to Catastrophic Failure of Water Storage Structures

Loss of life and damage to structures, roads, and utilities can result if a dam fails and the water impounded behind it is released suddenly. Several dams in the Newport Beach area and upstream from Newport Beach have the potential to inundate sections of the City if they fail catastrophically while their reservoirs are storing water.

Three dams located in the Newport Beach area fall under State jurisdiction: Big Canyon Reservoir, San Joaquin Reservoir, and Harbor View Dam. These dams are owned by the City of Newport Beach, the Irvine Water Company, and the County of Orange, respectively. They retain small reservoirs in the San Joaquin Hills. In addition, Bonita Canyon Dam, also located in Newport Beach, used to be under State Jurisdiction, but has been modified so that its crest elevation is now lower than it used to be, and below the threshold established by the State. All four dams have the potential to inundate localized sections of the City, but inundation maps showing the potential extent of this flooding are only available for Big Canyon, San Joaquin and Harbor View reservoirs (see Map 7-10). Portions of Newport Beach are also threatened by flooding from larger structures located inland from the City, but whose drainages flow through or adjacent to Newport Beach. These structures include Prado Dam, Santiago Creek Reservoir, and Villa Park Reservoir. If Seven Oaks Dam fails, the flow reportedly will be contained by Prado Dam Reservoir, and is therefore not expected to impact the City of Newport Beach. Each of these reservoirs is described further below.

Prado Dam reservoir straddles the boundary between San Bernardino and Riverside counties and is located approximately 2 miles west of the city of Corona. This dam is an earth-filled, concrete-capped structure that was completed in April 1941. Modifications to the dam that include raising the embankment and constructing new outlet works began in 2008, and were mostly completed by 2010. With the raising of the embankment the reservoir now covers an area of 10,256 acres (http://ocflood.com/sarp/prado; www.spl.usace.army.mil/), and has a new impoundment capacity of 362,000 acre-feet (http://ocflood.com/sarp/prado). Summary information on this dam and its reservoir are provided in Table 7-7, and for a picture of the dam, see Figure 7-14.

Flood maps that show the downstream inundation limits should this dam fail catastrophically using the new dam levels are not available and are not expected to be available before the year 2020 (http://www.spl.usace.army.mil/Media/FactSheets/tabid/1321/Article/477349/dam-safety-program.
aspx). Until then, Map 7-10 shows the projected southwestern limits of the flood inundation path near Newport Beach based on the original dam dimensions (purple zones). If this dam fails catastrophically while full of water, the inundation area will impact much of Orange County including Newport Beach, with flood waters reaching the City approximately 21.5 hours after dam failure (USACE, 1985). Flooding is expected to impact West Newport along the Santa Ana Delhi Channel

and San Diego Creek, and in Newport Bay as far south as the Coast Highway. Prior to the new modifications, it was estimated that more than 110,000 acres of residential, commercial, and agricultural land will be flooded. By the time floodwaters reach the ocean most areas from Long Beach to Newport Bay are likely to be inundated. Given the higher lake levels possible since the dam crest was raised, this map shows minimum inundation limits. Map 7-10 should be replaced if and when the U.S. Army Corps of Engineers release the new inundation maps for Prado Dam.

Table 7-7: Characteristics of Prado Dam and Reservoir

Name:	Prado
Department of Water Resources No.	9000-022
National ID No.	CA10022
Owner:	U.S. Army Corps of Engineers
Year Completed:	1941; enlarged in 2008-2010
Latitude; Longitude:	33.89°; -117.643°
Crest Elevation:	594.4 feet (new, post-2010 dimensions)
Stream:	Santa Ana River
Dam Type:	Earth-filled
Parapet Type:	N/A
Crest Length:	2,280 feet (prior to 2010)
Crest Width:	30 feet (prior to 2010, new width unknown)
Total Freeboard:	23 feet (prior to 2010)
Spillway crest elevation:	563 feet (new, post-2010 dimensions)
Material Volume:	3,389,000 cubic yards (prior to 2010)
Impoundment Capacity:	362,000 acre-feet (217,000 prior to 2010)
Drainage Area:	2,255 sq mi
Reservoir Area:	10,256 acres (new, post-2010 dimensions)

Map 7-10: Dam Failure Inundation Map

(a larger version of this map is available in Appendix H, as Plate H-9)

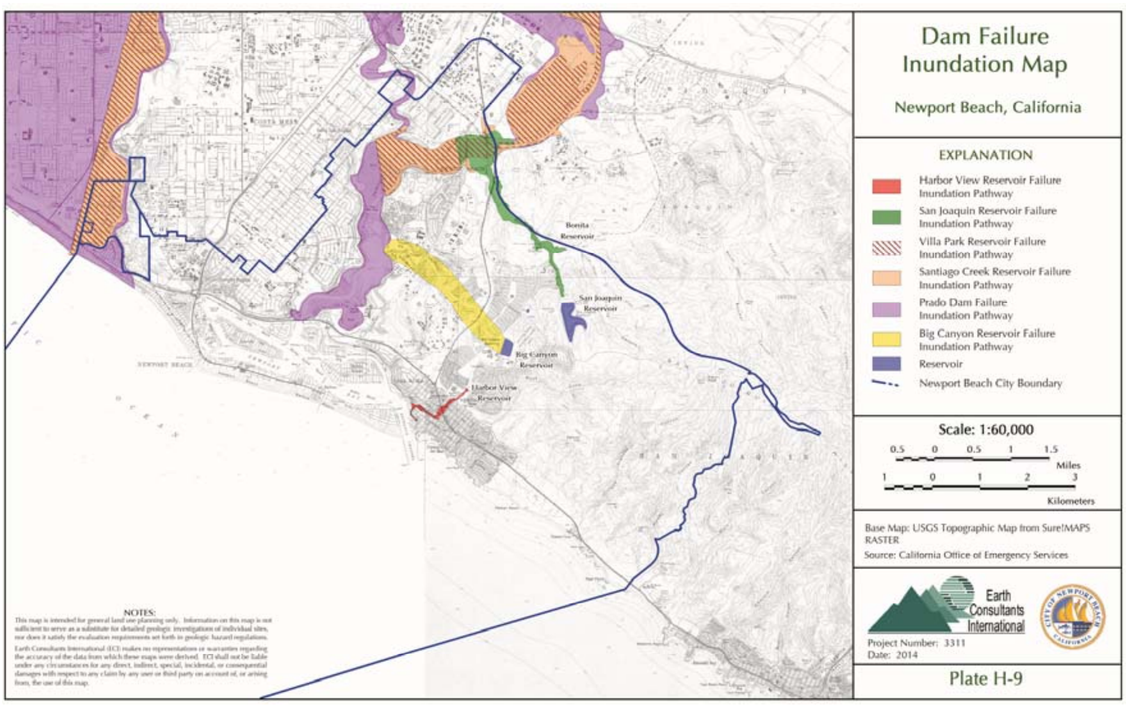


Figure 7-14: View to the North of Prado Dam (to the right-center), **and Prado Dam Reservoir** (in the Background)

(Photograph from www.spl.usace.army.mil/resreg/images/pradodam.jpg)

Prado Dam received a Dam Safety Action Class III (DSAC III) rating in December 2009 based on a Screening Portfolio Risk Analysis (SPRA) conducted in July 2009. A DSAC III rating is given to dams that are considered to be significantly inadequate, or when their probability of failure resulting in a combination of life, economic or environmental consequences is considered moderate to high. Prado Dam received a DSAC III rating because it has the potential for embankment seepage and piping, and because overtopping of the dam in the vicinity of the existing spillway are considered a possibility. Interim Risk Reduction Measures (IRRMs) that the Army Corps of Engineers have implemented include: 1) when the water level impounded behind the dam reaches an elevation of 528 feet, the dam shall be inspected by a Special Dam Inspection Team, and 2) the Emergency Action Plan needs to be updated annually.

Figure 7-15: View Upstream of Seven Oaks Dam

(Photograph from www.co.san-bernardino.ca.us/flood/dampage.htm)

Seven Oaks Dam is an earth and rock-filled dam (see Figure 7-15) located in San Bernardino County, approximately 8 miles northeast of the city of Redlands. Construction of the dam was completed in November 1999. Seven Oaks Dam was designed to protect San Bernardino County from flooding and to work in conjunction with Prado dam, which is located approximately 41 miles downstream, to provide 350-year flood protection. The reservoir has a capacity of 145,600 acre-feet and covers an area of 780 acres when full. Summary information on this dam and its reservoir are provided in Table 7-8. It is anticipated that the floodwaters resulting from a Seven Oaks dam failure would be contained by Prado dam and therefore would not pose a threat to Newport Beach.

Table 7-8: Characteristics of Seven Oaks Dam and Reservoir

Name:	Seven Oaks
Department of Water Resources No.	87-016
National ID No.	CA01530
Owners and Operators:	Orange County Flood Control District, San Bernardino County Flood Control District, and Riverside County Flood Control and Water Conservation District (built by the U.S. Army Corps of Engineers)
Year Completed:	1999
Latitude; Longitude:	34.1173°; -117.10°
Crest Elevation:	2610 feet
Stream:	Santa Ana River
Dam Type:	Rock
Parapet Type:	No Wall
Crest Length:	2,980 feet
Crest Width:	40 feet
Total Freeboard:	30 feet
Height:	550 feet
Material Volume:	38,000,000 cubic yards
Storage Capacity:	145,600 acre-feet
Drainage Area:	177 sq mi
Reservoir Area:	780 acres

Santiago Creek Reservoir dam is an earth-filled structure that has a storage capacity of 25,000 acre-feet. It is located 7 miles east of the city of Orange. Santiago Creek is the largest tributary to the lower Santa Ana River with a drainage basin area greater than 100 square miles. Summary information on this dam and its reservoir is provided in Table 7-9. The flood inundation path through Newport Beach, should the dam fail, is shown in orange shading on Map 7-10 and Plate H-9.

Villa Park Reservoir dam is located 3.5 miles downstream of Santiago Creek Reservoir, across Santiago Creek, and 4 miles east of the City of Orange downtown. Villa Park dam is an earth-filled structure that has a storage capacity of 15,600 acre-feet. Summary information on this dam and its reservoir is provided in Table 7-10. The flood inundation path through Newport Beach, should the dam fail, is shown on Map 7-10 with a stippled red pattern, within the drainage areas for the Santa Ana River and San Diego Creek.

Table 7-9: Characteristics of the Santiago Creek Dam and Reservoir

Name:	Santiago Creek
Department of Water Resources No.	75-000
National ID No.	CA00298
Owner:	Serrano Irrigation District & Irvine Ranch Water District
Year Completed:	1933
Latitude; Longitude:	33.7863°; -117.723°
Crest Elevation:	810 feet
Stream:	Santiago Creek
Dam Type:	Earth-filled
Parapet Type:	No wall
Crest Length:	1,425 feet
Crest Width:	10 feet
Total Freeboard:	16 feet
Height:	136 feet
Material Volume:	789,000 cubic yards
Storage Capacity:	25,000 acre-feet
Drainage Area:	63.1 sq mi
Reservoir Area:	650 acres

Table 7-10: Characteristics of the Villa Park Dam and Reservoir

Name:	Villa Park
Department of Water Resources No.	1012-000
National ID No.	CA00829
Owner:	County of Orange
Year Completed:	1963
Latitude; Longitude:	33.8163°; -117.765°
Crest Elevation:	584.3 feet
Stream:	Santiago Creek
Dam Type:	Earth-filled
Parapet Type:	No wall
Crest Length:	119 feet
Crest Width:	20 feet
Total Freeboard:	18.3 feet
Height:	118 feet
Material Volume:	835,000 cubic yards
Storage Capacity:	15,600 acre-feet
Drainage Area:	83.4 sq mi
Reservoir Area:	480 acres

Harbor View Dam is a small earth-filled structure; its reservoir is usually empty and used primarily for flood control. It is located approximately 700 feet upstream of Harbor View School, in Newport Beach, and has a storage capacity of 28 acre-feet. Summary information on this dam and its reservoir is provided in Table 7-11. The flood inundation path through Newport Beach, should the dam fail while full, is shown in red on Map 7-10.

Table 7-11: Characteristics of the Harbor View Dam and Reservoir

Name:	Harbor View
Department of Water Resources No.	1012-002
National ID No.	CA00830
Owner:	County of Orange
Year Completed:	1964
Latitude; Longitude:	33.6043°; -117.865°
Crest Elevation:	190 feet
Stream:	Jasmine Gulch
Dam Type:	Earth-filled
Parapet Type:	No wall
Crest Length:	330 feet
Crest Width:	60 feet
Total Freeboard:	20 feet
Height:	65 feet
Material Volume:	63,000 cubic yards
Storage Capacity:	28 acre-feet
Drainage Area:	0.39 sq mi
Reservoir Area:	3 acres

San Joaquin Dam is an earth-filled structure with a clay lining and asphalt surfacing. It is located in Newport Beach approximately half a mile east of Spyglass Hill Road. Its reservoir has a storage capacity of 3,036 acre-feet and an area of 50 acres; water in the reservoir is used for seasonal reclaimed water purposes. The reservoir maximizes storage during the winter months, with water withdrawn during the summer months, to provide landscape irrigation water for the cities of Irvine, and portions of Newport Beach, with an emphasis on Newport Coast. Summary information on this dam and its reservoir is provided in Table 7-12; Figure 7-16 shows a photograph of the dam. The flood inundation path through Newport Beach, should the dam fail, is shown in green on Map 7-10 (and Plate H-9 in Appendix H)..

Table 7-12: Characteristics of the San Joaquin Dam and Reservoir

Name:	San Joaquin
Department of Water Resources No.	1029-000
National ID No.	CA00853
Owner:	Irvine Ranch Water District
Year Completed:	1966
Latitude; Longitude:	33.6202°; -117.842°
Crest Elevation:	476 feet
Stream:	Tributary to Bonita Creek
Dam Type:	Earth-filled
Parapet Type:	No wall
Crest Length:	873 feet
Crest Width:	30 feet
Total Freeboard:	5.5 feet
Height:	224 feet
Material Volume:	1,911,000 cubic yards
Storage Capacity:	3,036 acre-feet
Drainage Area:	0.35 sq mi
Reservoir Area:	50 acres

Figure 7-16: View of San Joaquin Dam (at the top) and Reservoir
(North is to the top; photo courtesy of the City of Newport Beach; December 2007)

Bonita Dam is an earth-filled structure located approximately one mile downstream (north) of San Joaquin Dam on Bonita Creek. Although (pre-2011) it has the same reservoir area (50 acres) as San Joaquin Dam, it has a storage capacity of only 323 acre-feet. Summary information on this dam and its reservoir is provided in Table 7-13; please note that this information predates the modifications made to the dam that now exclude it from the State listing of dams. Modifications that reportedly were made to this structure include the construction of an earthen buttress on the existing dam face, the rehabilitation of the existing spillway, building a new plunge pool at the bottom of the rehabilitated spillway, increasing the spillway capacity, and constructing a permanent access road. These changes have increased the seismic stability of the dam (http://www.rbf.com/projects/projects.asp?id=136). The flood inundation path through Newport Beach, should the dam fail, is not available.

Big Canyon Dam is an earth-filled, asphalt-lined structure that provides fire protection and drinking water to residents of Newport Beach. The reservoir impounds sufficient water to supply the City for seven days. It has a storage capacity of 600 acre-feet and is located in a residential area near Pacific View Memorial Park and Lincoln School. The reservoir is covered with a polypropylene tarp that is meant to protect the water from debris. Failure of this structure would reportedly produce a flood wave between 300 and 1,000 feet wide on its course to Newport Bay. The limits of the inundation area, should this facility fail catastrophically, are shown in yellow on Map 7-10. However, failure is thought unlikely because a seismic analysis of the Big Canyon Dam shows that it can withstand a maximum magnitude earthquake (M = 7) on the Newport-Inglewood fault. This earthquake is anticipated to produce very strong ground motions, with a peak horizontal ground acceleration of 0.91g, in the area of the reservoir (URS, 2001). Summary information on this dam and its reservoir is provided in Table 7-14; a photograph of the reservoir is shown in Figure 7-17.

Table 7-13: Characteristics of the Bonita Dam and Reservoir

Name:	Bonita Canyon
Department of Water Resources No.	793-004
National ID No.	CA00747
Owner:	The Irvine Company
Year Completed:	1938
Latitude; Longitude:	33.632°; -117.848°
Crest Elevation:	151 feet (prior to 2011)
Stream:	Bonita Creek
Dam Type:	Earth-filled
Type:	No wall
Crest Length:	331 feet
Crest Width:	20 feet
Total Freeboard:	8 feet (prior to 2011)
Height:	51 feet (prior to 2011)
Material Volume:	43,000 cubic yards
Storage Capacity:	323 acre-feet
Drainage Area:	4.2 sq mi
Reservoir Area:	50 acres

There are currently no above-ground water tanks in Newport Beach, although at least one 3.4 million gallon reservoir has been proposed in the Irvine Coast Development along Pelican Hill Road (The Irvine Company, 1988). Any above-ground storage tanks proposed and built in the City need to be designed to the most current seismic design standards for liquid storage tanks. Any future tanks proposed and built in the City would be vulnerable to damage as a result of ground deformation, strong ground shaking, and locally, to surface fault rupture. Because the entire City of Newport Beach is susceptible to strong seismic ground motion, any future water tanks should incorporate earthquake resistant designs, including flexible pipe joints.

Table 7-14: Characteristics of the Big Canyon Dam and Reservoir

Name:	Big Canyon
Department of Water Resources No.	1058-000
National ID No.	CA00891
Owner:	City of Newport Beach
Year Completed:	1959
Latitude; Longitude:	33.6121°; -117.857°
Crest Elevation:	308 feet
Stream:	Tributary of Big Canyon Creek
Dam Type:	Earth-filled
Parapet Type:	No wall
Crest Length:	3,824 feet
Crest Width:	20 feet
Total Freeboard:	5.5 feet
Height:	65 feet
Material Volume:	508,000 cubic yards
Storage Capacity:	600 acre-feet
Drainage Area:	0.04 sq mi
Reservoir Area:	22 acres

Figure 7-17: View of Big Canyon Dam and Reservoir
(North to the top; photo courtesy of City of Newport Beach; December 2007)

Inundation Due to Hurricanes and Tropical Storms

Tropical cyclones are great masses of warm, humid, rotating air that occur between 10° and 25° latitude on both sides of the equator. Large tropical cyclones, those with wind speeds greater than 119 km/hr (74 mi/hr), are referred to as hurricanes in the North Atlantic and the Eastern Pacific Oceans (Garrison, 2002). Hurricane season, the time of the year when most hurricanes are generated, runs from June to the end of November, with peak activity from mid-August to late October (http://hurricanes.noaa.gov). Most hurricanes that affect the Southern California region are generated in the southern portion of the Gulf of California. Although only one hurricane-strength storm has been reported in Southern California – the 1858 hurricane in San Diego mentioned in Table 10-4 – many tropical storms, those with wind speeds less than 119 km/hr (74 mi/hr), have caused damage to southern California in the past.

The main hazards associated with tropical cyclones, and especially hurricanes, are storm surge, high winds, heavy rain, flooding, and tornadoes. The greatest potential for loss of life related to a hurricane for coastal communities is from the storm surge, which if combined with normal tides can increase the mean water level by 15 ft (4.6 m) or more (http://hurricanes.noaa.gov). Waves that high would breach or extend over the Balboa Peninsula and impact all development adjacent to the coastline, including areas along Corona del Mar and Crystal Cove. Even higher waves can be expected if the storm surge occurs during high tide.

Tropical storm-force winds and waves are strong enough to be dangerous to those caught in them. Water weighs approximately 1,700 pounds per cubic yard; therefore, extended pounding by frequent waves can demolish any structure not designed to withstand such forces. Hurricane and tropical-force winds can easily destroy poorly constructed buildings and mobile homes (see Section 10 – Windstorms). Debris such as signs, roofing material, and small items left outside become flying missiles in hurricanes. Extensive damage to trees, towers, underground utility lines (from uprooted trees), and fallen poles cause considerable disruption. High-rise buildings are also vulnerable to hurricane-force winds, particularly the upper floors, since wind speed tends to increase with height. It is not uncommon for high-rise buildings to suffer a great deal of damage, typically due to windows being blown out. Consequently, the areas around these buildings can be very dangerous.

Widespread rainfall of 6 to 12 inches (15 to 30 cm) is common during the landfall of a hurricane or tropical storm, frequently producing deadly and destructive floods. Such floods have been the primary cause of tropical cyclone-related fatalities over the past 30 years worldwide (http://hurricanes.noaa.gov). Hurricanes can also produce tornadoes that add to the storm's destructive power. In general, tornadoes associated with hurricanes are less intense than those that occur in the Central Plains area of the United States, but can still be locally devastating (see Section 10 for additional, more in-depth discussion on tornadoes in the Southern California area). Interestingly, some hurricanes produce no tornadoes, while others produce multiple ones. Either way, the effects of tornadoes, added to the larger area of hurricane-force winds, can produce substantial damage (http://hurricanes.noaa.gov).

Although only one hurricane-strength storm has reportedly hit the Southern California area in historical times, damage from wave swell and weather related to hurricanes that develop in the Baja California area has been reported in the region. Swells caused by offshore storms and hurricanes in Baja California can cause localized flooding and erosion of the Southern California coastline. Furthermore, historically, only one tropical-strength storm has made a landfall in Southern California: Near the end of September 1939, a tropical storm with sustained winds of 80.5 km/hr (50 mi/hr) came ashore at Long Beach. The storm generated five inches of rain in the Los Angeles basin on September 25th, and between 6 and 12 inches (15 and 30.5 cm) of rain in the surrounding mountains. In Newport Beach, this storm produced 30-foot high waves (as high as a three-story building) that tore away half of Newport Pier and destroyed most of Balboa Pier, damaged portions of the jetties, several homes and small vessels, and caused numerous drownings (P. Alford, personal communication, 2002). Other less severe but still significant storms that impacted the Southern California coastline occurred during 1927, 1938-1939, 1941, 1969, 1977-1978, 1983, 1988 (Kuhn and Sheppard, 1984; Walker et al., 1984; Pipkin et al., 1992), and even more recently in 1995, 1997-1998, and 2005. Many of these wet winters have been associated with El Niño events. More information about these storms is provided in Section 10 – Windstorms, and specifically, on Table 10-3.

In February 1994, an unusually strong westerly jet stream brought high winds and up to 3 inches of rainfall to Southern California. Serious flooding occurred in Newport Beach and Irvine. In Newport Beach, several schools flooded, whereas several landslides and mudslides occurred in various areas of southern Orange County and northern San Diego County.

Inundation Due to Sea Level Rise

Previous studies suggest that a 1 m (~39 in) rise in sea level would generally cause beaches to erode 200 to 400 m (650 to 1,300 ft) along the California coast (Wilcoxen, 1986). Given that the width of the beaches in Newport Beach varies between 15 and 190 m (50 and 600 ft), a sea level rise of as little as 15 cm (6 in) could have a negative impact on the low-lying areas around Newport Bay that are not protected by bulkheads and seawalls. Sea level rise would also cause increased sea-cliff retreat in the southern portion of the City where the beaches are narrow, and the surf pounds at the base of the bluffs, eroding away the soft bedrock that forms the cliffs.

How long would it take for sea level to rise 15 cm (6 in) in Newport Beach at the current rate? Although a long-term record of sea-level measurements is not available for the Newport Beach area, a 40-year record suggests that, if global warming is not exacerbated in the next few decades, a 6-inch rise could occur in about 70 years. However, the California Ocean Protection Council has adopted projections that suggest that by 2030, sea level along the California coast will have risen about 7 inches above the year 2000 levels. So, a sea level rise of 6 inches in Newport Beach could occur in as little as two decades. Projections specific to Newport Beach are difficult to quantify given that there is no local gauge and variability in sea level along the coastline is expected. Currently, the closest sea level gauges are located in San Diego and Los Angeles; historically these gauges have measured a lower rate of sea level rise than that measured in Newport Beach between 1955 and 1995, when there was a sea level gauge there. Using the San Diego and Los Angeles gauge records mentioned above, it could take anywhere between 70 and 180 years for sea level in Newport Beach to rise 6 inches, assuming that global warming is not exacerbated in the next decades. Obviously, local measurements of relative sea level change are necessary to better quantify these estimates and make more realistic predictions.

Vulnerability Assessment - Community Flood Issues

Vulnerability assessment is the second step of flood-hazard assessment. It combines the flood-prone areas identified previously with an inventory of the property within those areas. Understanding the population and property exposed to this hazard can assist in reducing risk and preventing loss from future events.

This assessment was conducted using the databases provided by HazUS, a regional multi-hazard loss estimation software developed by FEMA and the National Institute of Building Sciences. The primary purpose of HazUS is to provide a methodology and software application to develop multi-hazard losses at a regional scale. These loss estimates can be used by local, state, and regional officials to plan and stimulate efforts to reduce risks from multi hazards, and to prepare for emergency response and recovery. Additional information regarding HazUS, including its uses and limitations, is provided in Section 6 – Earthquakes. A modified HazUS analysis that looked at the number of structures within the FEMA-mapped 100- and 500-year flood zones was conducted for this study. The results of the analysis are presented below, in the Risk Analysis section.

Typically, vulnerability assessments of flooding hazards involve assessing the amount of property in the floodplain, as well as the type and value of structures on those properties. Input to the program can include FEMA flood inundation zones, or site-specific engineering studies of flood potential prepared by others rather than FEMA. Once that is done, a working estimate for potential flood losses can then be calculated. We used the FEMA maps available for Newport Beach to identify potential flooding areas, and to estimate the losses due to flooding. Please note, however, that these estimates are considered minima, as the Advisory Committee agreed that the results obtained from the HazUS analysis significantly under-represent the anticipated losses due to flooding in Newport Beach.

What is Susceptible to Damage During a Flood Event?

The largest impact that flood events have on communities is the loss of life and property. During certain years, property losses resulting from flood damage are extensive. Property loss from floods strikes both private and public property. Although there has been no significant flooding in Newport Beach since at least 1983, as described above, localized flooding does occur sporadically, as the February 1994, 1998 and 2005 storm records show.

The type of property damage caused by flood events depends on the depth and velocity of the floodwaters. Faster moving floodwaters can wash buildings off their foundations and sweep cars downstream. Pipelines, bridges, and other infrastructure can be damaged when high waters combine with flood debris. Extensive damage can be caused by basement flooding and landslide damage related to soil saturation from flood events. Most flood damage is caused by water saturating materials susceptible to loss (i.e., wood, insulation, wallboard, fabric, furnishings, floor coverings, and appliances). In many cases, flood damage to homes renders them unlivable.

Risk Analysis

Risk analysis is the third and most advanced phase of a hazard assessment. It builds upon the hazard identification and vulnerability assessment. A flood risk analysis for the City of Newport Beach should include two components: 1) the life and value of property that may incur losses from a flood event (defined through the vulnerability assessment); and 2) the number and type of flood events expected to occur over time. Within the broad components of a risk analysis, it is possible to predict the severity of damage from a range of events. Flow velocity models can assist in predicting the amount of damage expected from different magnitudes of flood events.

As mentioned above, the results presented here are based on the FEMA maps available for Newport Beach and vicinity. More specific, but time-consuming and therefore costly analyses can be made using data that is based on a hydrological analysis of landscape features. Changes in the landscape, often associated with human development, can alter the flow velocity and the severity of damage that can be expected from a flood event. Using GIS technology and flow velocity models, it is possible to map the damage that can be expected from flood events over time. It is also possible to estimate the effects of certain flood events on individual properties. These site-specific analyses were not conducted at this time, however, we did conduct limited HazUS flooding analyses for Newport Beach that consider both the 100- and 500-year flood events. The results of these analyses are presented in the following sections. For a detailed description of the HazUS software and methodology, please refer to Section 6.

General Building Stock Exposure and Potential Building-Related Losses

Hundreds to thousands of residential and commercial structures in Newport Beach are at risk of being impacted by flooding due to their geographic location within the floodplain. Table 7-15 shows the (HazUS-generated) number of structures located within the 100- and 500-year floodplains of the Santa Ana River and San Diego Creek. (Please note that the 500-year flood zone associated with the Santa Ana River is almost exactly the same as its 100-year flood zone, which is why the building exposure numbers for the Santa Ana River did not change).

Table 7-15: Building Exposure to 100- and 500-Year Floods by Stream Source

Flood Source	100-Year Floodplain	500-Year Floodplain*
Santa Ana River		
Residential	833	833
Commercial	27	27
Total Santa Ana River	860	860
San Diego Creek		
Residential	1,839	5,168
Commercial	82	418
Total San Diego Creek	1,921	5,586
Totals	2,781	6,446

* Count in this column includes the buildings in the 100-year flood zone

Between approximately 2,800 and 6,500 structures in Newport Beach are at risk of being impacted by storm flooding given their location in the floodplain. These figures do not include structures outside of the mapped flood zones that could still be impacted by street flooding, debris flows, and localized runoff draining adjacent slopes.

Building-related losses can be divided into two categories: direct building losses and business interruption losses. Direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. In 2005, the average flood claim in the United States was $83,282, in great part due to losses from Katrina, whereas in 2013, the average flood claim was $26,175 (http://www.iii.org/media/facts/statsbyissue/flood/). Using these two claim values as a guide, dollar losses associated with a 100-year flood in Newport Beach could amount to between $73 and $233 million. Losses associated with a low-probability 500-year flood could amount to between $170 million and $541 million in Newport Beach. These costs do not include the harder-to-estimate business interruption losses associated with the inability to operate a business because of the damage sustained during the flood. This includes loss of income for business owners, and loss of wages for employees of facilities impacted by the flood. Business interruption losses also include temporary living expenses and relocation expenses for those people displaced from their homes because of the flood.

Statewide, the 1996 floods destroyed 156 housing units. Of those units, 61 percent were mobile homes and trailers. Many older manufactured home parks are located in floodplain or low-lying areas. **Manufactured homes** have a lower level of structural stability than stick-built homes, and must be anchored to provide additional structural stability during flood events (and for earthquake preparedness, also). Because of confusion in the late 1980s resulting from multiple changes in NFIP regulations, there are some communities that do not actively enforce anchoring requirements. The flood analysis conducted for this study indicates that there are two mobile home parks in the City located within the 100-year floodplain of the Santa Ana River. Therefore, during a major storm, several of the manufactured homes in the City of Newport Beach may be damaged by flooding.

Shelter Requirements

Given the number of residential structures located within the 100- and 500-year flood zones, a significant storm-induced flood has the potential to displace residents from their homes. These individuals may require accommodation in temporary public shelters. Using an average of 2.25 people per housing unit, and assuming that the residents in 70 percent of the housing units in the 100-year flood zone need to evacuate their homes temporarily during and immediately following the storm resolves in more than 4,000 people displaced. A similar analysis for housing units within the 500-year flood zone, and assuming that 50 percent of those residents would be displaced resolves into more than 6,750 people needing short-term shelter. Many are likely to find shelter with family and friends that live outside the flood zone, but the City may have to provide temporary shelter for several hundreds to a few thousand people if these low-probability but not unlikely flood events happen. Similar numbers of displaced individuals in need of short- to long-term shelter are estimated if the Newport Beach area is impacted by a tsunami generated by a nearby source, whether as a result of an earthquake on an offshore fault, or movement of a submarine landslide.

Expected Damage to Essential Facilities

Essential facilities include hospitals, fire stations, police stations, and schools. Several of the educational and government facilities in the City are expected to be at least slightly damaged as a result of flooding given their location in the flood zones. Specifically, Fire Station No. 4 is located within the 100-year flood zone; whereas Fire Station No. 1, Fire Station No. 2 and Newport Beach

Elementary School are all located within the 500-year flood zone. Fire Stations No. 6 and No. 8, and Newport Coast Elementary School are located near the 100-year flood zone, and, in the event of flooding, access to and from these facilities could be difficult. Similarly, several of the essential facilities in the southern and southwestern portions of the City, including Hoag Presbyterian Hospital, may be cut-off from the rest of the City by rising flood waters as a result of flooding. These observations are summarized in Table 7-16 below. For a pictorial analysis, compare Plate H-1 with maps 7-6, 7-8, 7-9, and 7-10. Given that several local schools reported flood damage as a result of the February 6th, 1998 storm that brought in about 3 inches of rainfall to the area, these loss estimations may under-represent the actual losses that could be expected to essential facilities in the City.

Table 7-16: Estimated Damage to Essential Facilities

Scenario Flood	Essential Facilities Likely to be Impacted by Flooding
100-Year	1 fire station; restricted access to and from 2 fire stations and at least one school
500-Year	3 fire stations, coast guard station and 1 school; access to hospital restricted from the south.
Tsunami Flooding	3 to 4 fire stations, 1 school, coast guard station; restricted access to hospital and one fire station
Dam Inundation	1 school; restricted access to City Hall and 1 fire station

Business/Industry

Storm-flooding events impact businesses by damaging property and by interrupting business. Flood events can cut off customer access to a business as well as close a business for repairs. Roof leaks can impact the contents; in extreme cases, leaks can cause damage to sensitive electrical equipment, with the potential to cause the affected business thousands of dollars in material losses and potential loss of revenue. A quick response to the needs of businesses affected by flood events can help a community maintain economic vitality in the face of flood damage. Responses to business damages can include funding to assist owners in elevating or relocating flood-prone business structures, and loans to make building improvements, such as new roofs. Given that there are several commercial structures within the 100- and 500-year flood zones, business-related losses associated with damage to the structures and their contents or inventory, and business interruption losses associated with lost wages, loss of income, and relocation and rental income losses can be anticipated.

Furthermore, flooding in Newport Beach, whether as a result of storms, tsunami or sea-level rise, has the potential to impact the entire Balboa Peninsula and islands within the Bay. Depending on the strength of the flooding event or cause, the beach and bay areas may experience erosion and loss of usable land. These areas draw thousands of weekend and seasonal visitors, and thus flooding damage can result in substantial economic losses for the segment of the community that depends on these tourist dollars.

Public Infrastructure

Publicly owned facilities are a key component of daily life for all citizens of Orange County, including Newport Beach residents. Damage to public water and sewer systems, transportation networks, flood control facilities, emergency facilities, and offices can hinder the ability of the government to deliver services. Government can take action to reduce risk to public infrastructure from flood events, as well as craft public policy that reduces risk to private property from flood events. History shows that extensive flooding of streets can be anticipated during a major storm, tsunami, or dam failure. Several essential service buildings, including fire stations and schools, are expected to be impacted by severe flooding associated with a 100-year or larger storm and other flooding sources, as indicated in Table 7-16 above. Sewer systems can be overwhelmed, forcing the release of partially treated sewage onto the bay and beach. The economic losses associated with the cleanup and repair of the flooded areas has not been quantified, but would be substantial.

During natural hazard events, or any type of emergency or disaster, dependable road connections are critical for providing emergency services. **Roads systems** in the City of Newport Beach are maintained by multiple jurisdictions. Federal, State, county, and city governments all have a stake in protecting roads from flood damage. Road networks often traverse floodplains and floodway areas. Transportation agencies responsible for road maintenance are typically aware of roads at risk from flooding. An extensive network of residential streets is expected to be impacted by storm flooding, in addition to sections of the Coast Highway, and to a lesser extent, the southern termination of Newport Boulevard, one of the most important arterials in the City.

Bridges are key points of concern during flood events because they are important links in road networks, river crossings, and they can be obstructions in watercourses, hindering the flow of water during flood events. Scour at highway bridges involves sediment-transport and erosion processes that cause streambed material to be removed from the bridge vicinity. Nationwide, several catastrophic collapses of highway and railroad bridges have occurred due to scouring and a subsequent loss of support of foundations. This has led to a nationwide inventory and evaluation of bridges (Richardson and others, 1993). As discussed in Section 6, there are several bridges in the Newport Beach area that are included in both the Federal Highway Administration's National Bridge Inventory (http://www.fhwa.dot.gov/bridge/nbi.cfm) and Caltran's Local Highway Bridge Program (http://www.dot.ca.gov/hq/LocalPrograms/hbrr99/hbrr99a.htm) list classified as either structurally deficient or functionally obsolete. The structurally deficient bridge, as of May 2, 2013 when the State issued the latest list of bridges, is the north-bound Jamboree Bridge over San Diego Creek. The functionally obsolete bridges in Newport Beach, per the State list, include the Via Lido bridge over West Lido Channel, the Marine Avenue bridge over Balboa Island Channel, the Park Avenue bridge over the Grand Canal, the 38th Street bridge over Rivo Alto, and the Park Avenue bridge over Waters Way. A bridge classified as structurally deficient either has a significant defect such that a speed or weight limit must be applied to the bridge to ensure its safety, or its approaches flood regularly. A functionally obsolete bridge is one whose design is not suitable for its current use, such as lack of safety shoulders or the inability to handle current traffic volume, speed, size, or weight.

Scour processes are generally classified into separate components, including pier scour, abutment scour, and contraction scour. ***Pier scour*** occurs when flow impinges against the upstream side of the pier, forcing the flow in a downward direction and causing scour of the streambed adjacent to the pier. ***Abutment scour*** happens when flow impinges against the abutment, causing the flow to change direction and mix with adjacent main-channel flow, resulting in scouring forces near the abutment toe. ***Contraction scour*** occurs when flood-plain flow is forced back through a narrower opening at the bridge, where an increase in velocity can produce scour. ***Total scour*** for a particular site is the combined effects from all three components. Scour can occur within the main channel, on the flood plain, or both. While different materials scour at different rates, the ultimate scour attained for different materials is similar and depends mainly on the duration of peak stream flow acting on the material (Lagasse and others, 1991).

The State of California participates in the bridge scour inventory and evaluation program and a state-designated inspector must inspect all state, county, and City bridges every two years. The inspections are rigorous, looking at everything from seismic capability to erosion and scour. The bridges in the City of Newport Beach are State, county, city, or privately owned. To date, we have not found any records to indicate that the bridges in the Newport Beach area have been evaluated for scour, but most have been either analyzed and/or retrofitted for seismic purposes, as discussed above. Based on aerial photographs, we conducted a generalized assessment that includes the identification and evaluation of bridges that may be susceptible to scour during storm events. We used the following assumption for this evaluation: Bridges that cross channelized streams have a lower risk of scour because the concrete lining of the bed and banks resists undermining and erosion of bridge piers, although in intense floods, the concrete lining can still fail. The lower reaches of the Santa Ana River have been entirely channelized; therefore damage due to bridge scour is low, but not completely unlikely, as evidenced by the damage caused by the 1980 floods. In contrast, all other streams in Newport Beach have earthen or riprap-covered beds and banks, which allow for bed erosion and potential loss of bridge support.

The banks of San Diego Creek are comprised of earthen material with rock riprap sections near bridge crossings. The Jamboree, Highway 73, and MacArthur bridge crossings could be threatened by scour during flooding of San Diego Creek. Similarly, Bonita Canyon has an engineered channel comprised of earthen banks and riprap bridge protection. The bridges at MacArthur Boulevard and Bison Avenue could also be at risk during storm flow. There are no significant bridges crossing Big Canyon, Buck Gully, Los Trancos Canyon, or Muddy Canyon, therefore bridge scour is not a concern along these streams. During a 100-year or larger flood event, the Coast Highway bridge crossing Newport Bay could be impacted by flooding.

Drainage problems are known to occur sporadically in some specific areas of Newport Beach. However, the City does not consider these drainage issues more than a nuisance, and has pumping equipment to deal with flooding in these low spots when necessary. However, a 100-year or larger flood in the area could overwhelm this system of pumps, leaving Balboa Island and other low-lying areas in the City, like the Balboa Peninsula, under water until the storm abates and the floodwaters retreat.

Inadequate maintenance of the **storm-water systems** can also contribute to the flood hazard in urban areas. Regular inspection of culverts and storm drains to remove debris that may obstruct the flow of water during storms should be conducted to reduce the potential impacts from flooding.

Sanitation and sewerage services in the City of Newport Beach are provided by the City, the Irvine Ranch Water District, and the Costa Mesa Sanitary District. Wastewater collected in these service areas is collected, treated and disposed by the Orange County Sanitation District. The Orange County Sanitation District currently has two operating facilities that treat wastewater from residential, commercial and industrial sources in 21 cities and three special districts in central and northwestern Orange County. These facilities are located in Huntington Beach and Fountain Valley. Two pump stations located in Newport Beach, the Rocky Point and Bitter Point sewer pump stations, were replaced in the last five years. The original stations had been built decades ago, and no longer met current safety, electrical and building codes, posing a risk of sewage spills if incoming flows exceeded the pump stations' capacities. Beginning in the summer of 2013, the Orange County Sanitation District started a five-year program to rehabilitate several of the trunk sewer lines that extend into Newport Beach, typically enlarging the size of the sewer lines to accommodate larger flows. The five projects in Newport Beach include the Balboa Trunk, the District 6 Trunk Sewer Relief Project, the Dover Drive Trunk, the Newport Force Main, and the Southwest Costa Mesa Trunk. As of the writing of this report, the Balboa Trunk construction had been completed, and the Dover Drive Trunk and Newport Force Main projects were in construction (http://www.ocsd.com/residents/newport-beach-program). For additional information regarding these projects, refer to the Orange County Sanitation District's website at www.ocsd.com.

High water levels and runoff associated with short-term flooding as a result of storms (and possibly even a tsunami) can cause significant damage to infrastructure such as sewer and solid waste systems. Increased runoff during a downpour can result in sewage overflows into rivers, bays and the ocean, resulting in short-term contamination of surface waters with pathogens. Although the sewer lines extending into Newport Beach have been or are being replaced to accommodate larger flows, the larger flows they are being designed and constructed for are the result of increased urbanization. During heavy rains these pipes have to carry both the increased waste water generated by urbanization, and the storm waters; the resulting volumes may exceed the capacity of the pipes, even the newer ones. If this happens, untreated sewage would be discharged into the bay and ocean, as discussed before.

Current Flood Mitigation Activities

Recent storms have shown that flood damages to structures and businesses can cost thousands if not millions of dollars to repair. In most cases, these loss estimates do not even include lost revenue due to business interruption. The City of Newport Beach works to address its localized flooding problems both proactively and as they arise. Flooding mitigation activities include current mitigation programs and activities that have been and are being implemented by developers, residents, and State and City agencies. Some of the programs currently being administered by the City and other local agencies that help to reduce the City's vulnerability to flooding hazards are briefly described below. For additional information regarding the mitigation measures that the City has already implemented and will be implementing to reduce its flood hazard, refer to Sections 5 and 4 respectively.

Studies Prior to Development

All proposed large development projects require a site-specific hydrological evaluation to determine the potential impacts that development of the project may have on the flooding potential of the site and adjacent properties downgradient. As discussed in Section 9 – Landslides, geotechnical studies are also required to evaluate the potential for debris flows to impact the project and adjacent sites. Development in the 100-year flood zones is generally prohibited. Flood insurance is required for all structures located in the FEMA flood zones. Flood insurance is also recommended for structures outside the flood zones, but in areas that could be impacted by debris flows or mudflows.

Acquisition and Protection of Open Space in the Floodplain

Current efforts to increase public open space in Southern California are been paired with the need to restore and preserve natural systems that provide wildlife habitat and help to mitigate flood events. Public parks and publicly owned open spaces can provide a buffer between flood hazards and private property. This has been done extensively in the eastern portion of Newport Beach, where approximately 90 percent of the Newport Coast development area has been and will be left undeveloped as open space.

Improvements to the Water District's Infrastructure

Water service in the City is provided by the City, the Irvine Ranch Water District and the Mesa Consolidated Water District. Each of these agencies maintains a capital improvement program. Many water districts in the region are in the process of replacing old cast iron pipes with more ductile iron pipes, which will be more resilient in disaster situations. Water districts in the region are committed to working together during a disaster to provide water to the area's residents as soon as possible in the event that the water distribution system fails locally.

Stormwater Systems and Surface Water Quality

Storm drainage systems in Newport Beach are provided and maintained by the City, Orange County, and local community associations. In general, the County is responsible for maintaining the regional flood control system, while the City is responsible for local improvements. Each of these agencies maintains master and capital improvement plans. They all are required to conform to regional, state and federal regulatory requirements, including those pertaining to control of the discharge from municipal storm sewer systems to protect the environmental quality of surface waters.

Environmental quality problems include bacteria, toxins, and pollution. "Out of sight, out of mind" has traditionally been a common approach to dealing with trash, sediment, used motor oil, unused paint and thinner, and other hazardous substances that people dump into the sewer or storm drains. However, these substances eventually make their way into the rivers and oceans, where they can sicken surfers and swimmers, and endanger wildlife. The Clean Water Act of 1972 originally established the National Pollutant Discharge Elimination System (NPDES) to control wastewater discharges from various industries and wastewater treatment plants, known as "point sources," defined as discrete conveyances such as pipes or direct discharges from businesses or public agencies. In 1987, the Water Quality Act amended the NPDES permit system to include "nonpoint source" pollution; this refers to the introduction of bacteria, sediment, oil and grease, heavy metals, pesticides, fertilizers and other chemicals into our rivers, bays and oceans from less defined sources. These pollutants are washed away from roadways, parking lots, yards, and other areas by rain and dry-weather urban runoff, entering the storm drains, and ultimately the area's streams, bays and ocean.

The National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point and nonpoint sources that discharge pollutants into waters of the United States. The City of Newport Beach is a Co-permittee in NPDES Permit No. CAS 618030 with the Orange County Flood Control District, the County of Orange and the incorporated cities in the Santa Ana region of the California Regional Water Quality Control Board. Each Co-permittee owns or operates a Municipal Separate Storm Sewer System (MS4). The NPDES permit directs each of the Co-permittees to keep pollutants out of its MS4 to the maximum extent practicable and to ensure that dry-weather flows entering recreational waters from the MS4 do not cause or contribute to exceedances of water quality standards. Some of the actions that the Permit requires the City of Newport Beach to enforce include the following:

- ✓ Control contaminants into storm drain systems;
- ✓ Educate the public about stormwater impacts;
- ✓ Detect and eliminate illicit discharges;
- ✓ Control runoff from construction sites;
- ✓ Implement "best management practices" or "BMPs" and site-specific runoff controls for new development and redevelopment; and
- ✓ Prevent pollution from municipal operations, including fixed facilities (like City Hall and fire stations) and field activities (like trash collection).

Non-point pollutants will generally enter the stormwater system and surface waters of the area during strong rainstorm events that create runoff. Stronger or more common rainstorms in the region as a result of climate change have the potential to result in increased flows of storm water impacted with sediment and contaminants like lead, and petroleum hydrocarbons.

However, given that some areas in Newport Beach appear to be more susceptible to flooding issues, due in great part to high tides and short but intense rainfall, as well as urban run off and modification of the natural environment, proactive measures that address the issues before flooding occurs could be implemented.

Tsunami Evacuation System

City of Newport Beach officials have recognized that the area is vulnerable to a low-probability but high-risk tsunami event, with the highest risk posed by a local tsunami source that will not allow for much warning before the first wave hits land. Limited roads into and out of the Newport Peninsula and the islands in Newport Bay, the areas at higher risk of being impacted by a tsunami, may limit the effectiveness of the evacuation efforts. As a result, people in the area are encouraged to evacuate to higher ground on foot, if at all possible. The City of Newport Beach has installed signs in tsunami hazard zones identifying the risk and showing the evacuation routes to take to higher ground. In addition, the City has developed brochures and other informational materials describing its tsunami hazard and what to do before, during and immediately after an earthquake that could generate a tsunami. For a direct link to the City's informational materials, go to http://www.newportbeachca.gov/index.aspx?page=1495.

Potential Human Actions in Response to Sea Level Change

The City of Newport Beach has started to evaluate its options and potential mitigation measures to respond to sea level rise due to climate change. Human response to sea level changes include: 1) no action, 2) use of barriers, such as levees, to protect the built areas, 3) raising the coastline by placing sand on the beach and raising the buildings and supporting infrastructure, and 4) retreat (Titus, 1990; Nordstrom, 2000). Problems resulting from the no-action option include loss of recreational beaches due to accelerated erosion, loss of bayside property through erosion and inundation of low-lying areas, and stranding of buildings and infrastructure on the beach. As residents move inland, there is increased competition for land and living space, and natural resources in the backbays become increasingly threatened. Eventually, abandonment of the barrier reefs or peninsulas, and islands in the bays could become necessary. This option however, is not likely to happen in the near future in areas like Newport Beach, where there is a strong social, economic, and cultural need to maintain the integrity of the beaches, harbors and islands, and there are economic resources available to implement other options.

The second option involves construction of seawalls and other flood protection structures around the threatened areas. The most significant advantage of this option is that major institutional changes in land use are not required (Titus, 1990; Nordstrom, 2000). Lots, houses and roads would not have to be raised or moved. However, the increased water levels around the bulkheads, seawalls and other artificial structures would result in increased breaking wave energy, higher storm runup, and increased beach loss. Structures would have to be designed or improved to withstand these environmental assaults. Beaches could be maintained by artificial nourishment, but at a great cost and frequency.

The third option is probably cost-prohibitive in most areas. This would require placing sand on the beach to raise the ground surface, and raising the buildings and supporting infrastructure. Borrowing the large volumes of sand required would no doubt trigger environmental issues that would prohibit implementation of this option. Even if this were accomplished at the local level, raising the beach could increase the likelihood of bayshore erosion (Titus, 1990).

Retreat is the most environmentally sensitive option, but it involves new legislation that allows for land acquisition by public authorities, use of setback lines and prohibition of reconstruction after damage. The economic and social costs of land loss and compensation issues make this option unpalatable to most; strong political and public opposition can be expected. In intensely developed, premium real estate areas like Newport Beach, implementation of this option is very unlikely. Nevertheless, if sea levels do rise substantially, this will ultimately prove to be the most cost-effective and possibly only option.

Flood Resource Directory

The following resource directory lists the resources and programs that can assist county communities and organizations. The resource directory will provide contact information for local, county, regional, State and Federal programs that deal with natural hazards. For additional information, refer to Appendix A.

County and Local Resources

Orange County Public Works Department
333 West Santa Ana Boulevard
Santa Ana, California 92701
Ph: 714-834-5400
http://www.ocwd.com

Sanitation District of Orange County
10844 Ellis Avenue
Fountain Valley, California 92708
Ph: 714-962-2411
http://www.ocsd.com

Irvine Ranch Water District
15600 Sand Canyon Ave
Irvine, CA 92618
Ph: 949-453-5300
http:// www.irwd.com

Mesa Consolidated Water District
1965 Placentia Ave
Costa Mesa, CA 92627
Ph: 949-631-1200
http://www.mesawater.org

Costa Mesa Sanitary District
628 W. 19th Street
Costa Mesa, California 92627
http://www.cmsdca.gov/

State Resources

Governor's Office of Emergency Services (Cal OES)
P.O. Box 419047
Rancho Cordova, CA 95741-9047
Ph: 916 845- 8911
Fx: 916 845- 8910

California Resources Agency
1416 Ninth Street, Suite 1311
Sacramento, CA 95814
Ph: 916-653-5656

California Department of Water Resources (DWR)
1416 9th Street
Sacramento, CA 95814
Ph: 916-653-6192

California Department of Conservation: Southern California Regional Office
655 S. Hope Street, #700
Los Angeles, CA 90017-2321
Ph: 213-239-0878
Fx: 213-239-0984

Federal Resources and Programs

Federal Emergency Management Agency (FEMA)
FEMA provides maps of flood hazard areas, various publications related to flood mitigation, funding for flood mitigation projects, and technical assistance. FEMA also operates the National Flood Insurance Program. FEMA' s mission is to reduce loss of life and property and protect the nation's critical infrastructure from all types of hazards through a comprehensive, risk-based, emergency management program of mitigation, preparedness, response and recovery.

Federal Emergency Management Agency, Region IX
1111 Broadway, Suite 1200
Oakland, CA 94607
Ph: 510-627-7100
Fx: 510-627-7112

Federal Emergency Management Agency, Mitigation Division
500 C Street, S.W.
Washington, D.C. 20472
Ph: 202-566-1600

FEMA' s List of Flood Related Websites
This site contains a long list of flood related Internet sites from "American Heritage Rivers" to "The Weather Channel" and is a good starting point for flood information on the Internet.
Contact: Federal Emergency Management Agency, Phone: (800) 480-2520
Website: http://www.fema.gov/nfip/related.htm

National Flood Insurance Program (NFIP)
In Southern California, many cities lie within flood zones as defined in FEMA Flood Maps. The City of Newport Beach is a community within a designated flood zone. As a result, flood insurance is available to citizens in the floodzone that adopt and implement NFIP building standards. The standards are applied to development that occurs within a delineated floodplain, a drainage hazard area, and properties within 250 feet of a floodplain boundary. These areas are depicted on federal Flood Insurance Rate Maps available through the county.
National Floodplain Insurance Program (NFIP)
500 C Street, S.W.

Washington, D.C. 20472
Ph: 202-566-1600

Other National Resources

The Floodplain Management Association

The Floodplain Management website was established by the Floodplain Management Association (FMA) to serve the entire floodplain management community. It includes full-text articles, a calendar of upcoming events, a list of positions available, an index of publications available free or at nominal cost, a list of associations, a list of firms and consultants in floodplain management, an index of newsletters dealing with flood issues (with hypertext links if available), a section on the basics of floodplain management, a list of frequently asked questions (FAQs) about the Website, and a catalog of Web links.
Floodplain Management Association
P.O. Box 50891
Sparks, NV 89435-0891
Ph: 775-626-6389
Fx: 775-626-6389

The Association of State Floodplain Managers

The Association of State Floodplain Managers is an organization of professionals involved in floodplain management, flood hazard mitigation, the National Flood Insurance Program, and flood preparedness, warning, and recovery. ASFPM fosters communication among those responsible for flood hazard activities, provides technical advice to governments and other entities about proposed actions or policies that will affect flood hazards, and encourages flood hazard research, education, and training. The ASFPM Web site includes information on how to become a member, the organization's constitution and bylaws, directories of officers and committees, a publications list, information on upcoming conferences, a history of the association, and other useful information and Internet links.
Contact: The Association of State Floodplain Managers
Address: 2809 Fish Hatchery Road, Madison, WI 53713 Phone: (608) 274-0123
Website: http://www.floods,org

National Weather Service

The National Weather Service provides flood watches, warnings, and informational statements for rivers in the City of Newport Beach.
National Weather Service
520 North Elevar Street
Oxnard, CA 93030
Ph: 805-988- 6615

Office of Hydrology, National Weather Service

The National Weather Service s Office of Hydrology (OH) and its Hydrological Information Center offer information on floods and other aquatic disasters, This site offers current and historical data including an archive of past flood summaries, information on current hydrologic conditions, water supply outlooks, an Automated Local Flood Warning Systems Handbook, Natural Disaster Survey Reports, and other scientific publications on hydrology and flooding.
National Weather Service, Office of Hydrologic Development
1325 East West Highway, SSMC2
Silver Spring, MD 20910
Ph: 301-713-1658
Fx: 301-713-0963

National Resources Conservation Service (NRCS), US Department of Agriculture
NRCS provides a suite of federal programs designed to assist state and local governments and landowners in mitigating the impacts of flood events. The Watershed Surveys and Planning Program and the Small Watershed Program provide technical and financial assistance to help participants solve natural resource and related economic problems on a watershed basis. The Wetlands Reserve Program and the Flood Risk Reduction Program provide financial incentives to landowners to put aside land that is either a wetland resource, or that experiences frequent flooding. The Emergency Watershed Protection Program (EWP) provides technical and financial assistance to clear debris from clogged waterways, restore vegetation, and stabilizing riverbanks. The measures taken under EWP must be environmentally and economically sound and generally benefit more that one property.
National Resources Conservation Service
14th and Independence Ave., SW, Room 5105-A
Washington, DC 20250
Ph: 202-720-7246
Fx: 202-720-7690

USGS Water Resources (http:// water.usgs.gov)
This web page offers current US water news; extensive current (including real-time) and historical water data; numerous fact sheets and other publications; various technical resources; descriptions of ongoing water survey programs; local water information; and connections to other sources of water information.
USGS Water Resources
6000 J Street Placer Hall
Sacramento, CA 95819-6129
Ph: 916-278-3000
Fx: 916-278-3070

Bureau of Reclamation
The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public. The Bureau provides leadership and technical expertise in water resources development and in the efficient use of water through initiatives including conservation, reuse, and research. It protects the public and the environment through the adequate maintenance and appropriate operation of Reclamation's facilities and manages Reclamation's facilities to fulfill water user contracts and protect and/or enhance conditions for fish, wildlife, land, and cultural resources.
Mid Pacific Regional Office
Federal Office Building
2800 Cottage Way
Sacramento CA 95825-1898
Ph: 916- 978-5000
Fax 916- 978-5599
http://www.usbr.gov/

Army Corps of Engineers
The Corps of Engineers administers a permit program to ensure that the nation's waterways are used in the public interest. Any person, firm, or agency planning to work in waters of the United States must first obtain a permit from the Army Corps of Engineers. The Corps is responsible for the protection and development of the nation's water resources, including navigation, flood control, energy production through hydropower management, water supply storage and recreation.
US Army Corps of Engineers

P.O. Box 532711
Los Angeles CA 90053- 2325
Ph: 213-452- 3921

American Public Works Association
2345 Grand Boulevard, Suite 500
Kansas City, MO 64108-2641
Ph: 816-472-6100
Fx: 816-472-1610

Publications

Federal Emergency Management Agency, 2011, Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Buildings in Coastal Areas: FEAM P-55, Fourth Edition, August 2011.
Provides mitigation guidance for local officials and professionals in building design and construction.

Federal Emergency Management Agency, 2011, Engineering Principles and Practices for Retrofitting Flood-Prone Residential Structures: FEMA P-259, Third Edition, December 2011.
Provides engineering design and economic guidance on what constitutes feasible and cost-effective retrofitting measures for flood-prone residential structures.

Federal Emergency Management Agency, 2010, Home Builder's Guide to Coastal Construction Technical Fact Sheet Series: FEMA P-499, December 2010.
This document contains a series of 37 fact sheets that provide technical guidance and recommendations concerning the construction of coastal residential buildings.

Federal Emergency Management Agency, 2009, Homeowners' Guide to Retrofitting: FEMA P-312, Second Edition, December 2009.
Guide specifically for homeowners who want information on protecting their houses from flooding. Homeowners who need clear information about the options available and straightforward guidance that will help make decisions. The guide is written for readers who have little or no knowledge of flood protection methods or building construction techniques.

Federal Emergency Management Agency, 2009, Vertical Evacuation from Tsunamis: A Guide for Community Officials: FEMA P646A, June 2009.
This publication presents information on how vertical evacuation can be used and encouraged at the state and local level. It is meant to help state and local government officials and interested citizens by providing them with the information they need to address the tsunami hazard in their community, help determine if vertical evacuation is an option they should consider, and if so, how to fund, design and build such a refuge.

Federal Emergency Management Agency, 2008, Guidelines for Design of Structures for Vertical Evacuation from Tsunamis: FEMA P646, June 2008.
This publication presents general information on tsunami hazards, guidance on determining the tsunami hazard, including the need for tsunami depth and velocity on a site-specific basis, different options for vertical evacuation from tsunamis, determining tsunami and earthquake loads and structural design criteria, and structural design concepts.

Federal Emergency Management Agency, 2000, Above the Flood: Elevating Your Floodprone House: FEMA 347, May 2000.
This publication show how floodprone houses in south Florida were elevated above the 100-year

flood level following Hurricane Andres and also presents alternative elevating techniques.

NFIP Community Rating System Coordinator's Manual
Indianapolis, IN.
This informative brochure explains how the Community Rating System works and what the benefits are to communities. It explains in detail the CRS point system, and what activities communities can pursue to earn points. These points then add up to the "rating" for the community, and flood insurance premium discounts are calculated based upon that "rating." The brochure also provides a table on the percent discount realized for each rating (1-10). Instructions on how to apply to be a CRS community are also included.
Contact: NFIP Community Rating System
Phone: (800) 480-2520 or (317) 848-2898
Website: http://www.fema.gov/nfip/crs

Floodplain Management: A Local Floodplain Administrator's Guide to the NFIP
This document discusses floodplain processes and terminology. It contains floodplain management and mitigation strategies, as well as information on the NFIP, CRS, Community Assistance Visits, and floodplain development standards.
Contact: National Flood Insurance Program Phone: (800) 480-2520
Website: http://www.fema,gov/nfip/

Flood Hazard Mitigation Planning: A Community Guide, (June 1997).
Massachusetts Department of Environmental Management.
This informative guide offers a 10-step process for successful flood hazard mitigation. Steps include: map hazards, determine potential damage areas, take an inventory of facilities in the flood zone, determine what is or is not being done about flooding, identify gaps in protection, brainstorm alternatives and actions, determine feasible actions, coordinate with others, prioritize actions, develop strategies for implementation, and adopt and monitor the plan.
Contact: Massachusetts Flood Hazard Management Program Phone: (617) 626-1250
Website: http://www.magnetstate.ma.us/dem/programs/mitigate

Reducing Losses in High Risk Flood Hazard Areas: A Guidebook for Local Officials, (February 1987), FEMA-116.
This guidebook offers a table on actions that communities can take to reduce flood losses. It also offers a table with sources for floodplain mapping assistance for the various types of flooding hazards. There is information on various types of flood hazards with regard to existing mitigation efforts and options for action (policy and programs, mapping, regulatory, non-regulatory). Types of flooding which are covered include alluvial fan, areas behind levees, areas below unsafe dams, coastal flooding, flash floods, fluctuating lake level floods, ground failure triggered by earthquakes, ice jam flooding, and mudslides.
Contact: Federal Emergency Management Agency Phone: (800) 480-2520
Website: http://www.fema,gov