

SECTION 6:

EARTHQUAKES

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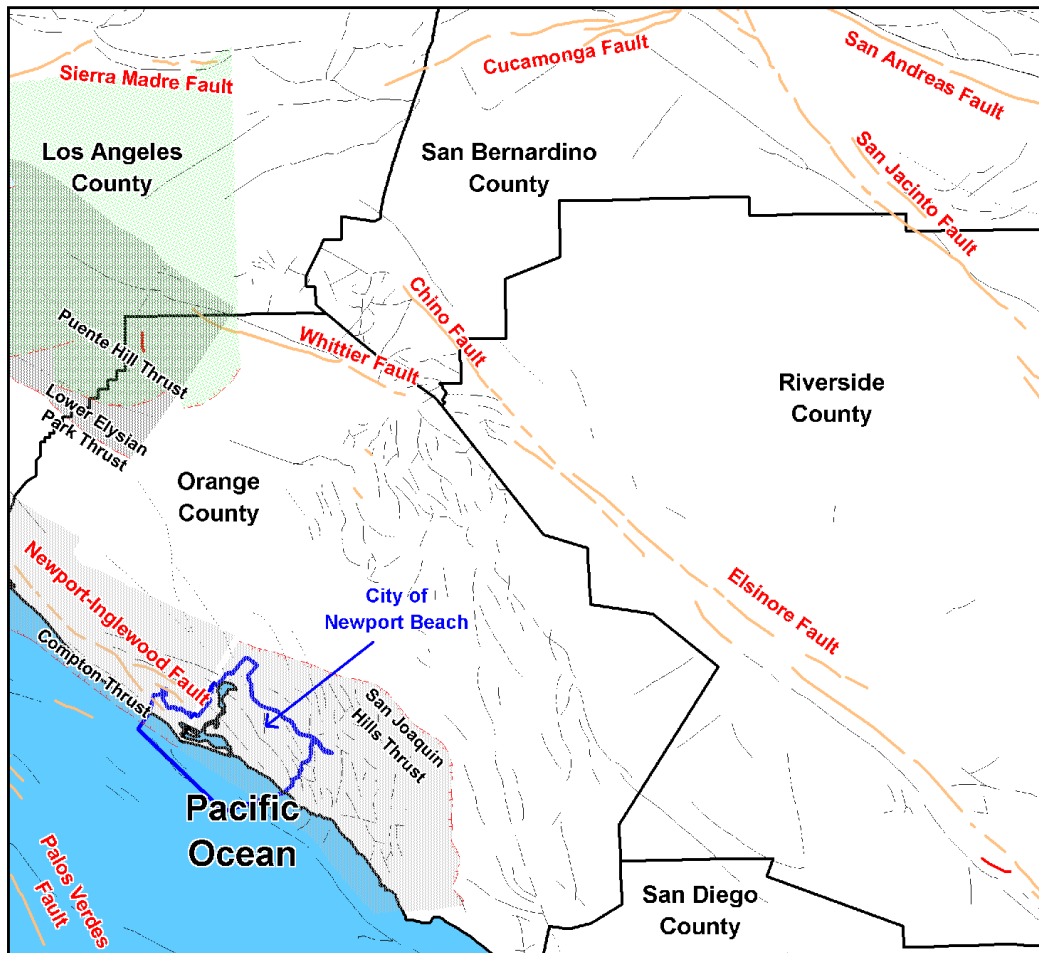
Why Are Earthquakes a Threat to the City of Newport Beach?

While Newport Beach is at risk from several natural and man-made hazards, an earthquake is the event with the greatest potential for far-reaching loss of life or property, and economic damage. This is true for most of Southern California, since damaging earthquakes occur relatively frequently, affect widespread areas, trigger many secondary effects, and can overwhelm the ability of local jurisdictions to respond. Earthquake-triggered geologic effects include ground shaking, surface fault rupture, landslides, liquefaction, subsidence, and seiches. Earthquakes can also cause human-made hazards such as urban fires, dam failures, and toxic chemical releases.

In California, recent earthquakes in or near urban environments have caused relatively few casualties. This is due more to luck than design. For example, when a portion of the Nimitz Freeway in Oakland collapsed at rush hour during the 1989, M_w 7.1 Loma Prieta earthquake, the freeway was uncommonly empty because so many were watching the World Series. The 1994 M_w 6.7 Northridge earthquake occurred before dawn, when most people were home safely in bed. Despite such good luck, California's urban earthquakes have resulted in significant losses. The moderate-sized Northridge earthquake caused 54 deaths, more than 1,500 injuries and nearly \$30 billion in damage. For days afterward, thousands of homes and businesses were without electricity; tens of thousands had no gas; and nearly 50,000 had little or no water. Approximately 15,000 structures were moderately to severely damaged, which left thousands of people temporarily homeless. Several collapsed bridges and overpasses created commuter havoc on the freeway system. Extensive damage was caused by ground shaking, with shaking-induced liquefaction and dozens of fires after the earthquake causing additional damage. This moderately sized earthquake resulted in record economic losses, and yet Newport Beach is at risk from earthquakes that could release more than ten times the seismic energy of the Northridge earthquake.





Historical and geological records show that California has a long history of seismic events. The state is probably best known for the San Andreas fault, a 750-mile-long fault running from the Mexican border to a point offshore west of San Francisco. Geologic studies show that over the past 1,400 to 1,500 years, large earthquakes have occurred on the southern San Andreas fault at about 130-year intervals. As the last large earthquake on the southern San Andreas occurred in 1857, that section of the fault is considered a likely location for an earthquake within the next few decades. The San Andreas fault, however, is only one of dozens of known faults that underlie southern California. Some of the better-known faults include the Sierra Madre, Newport-Inglewood, Whittier, Elsinore, Hollywood, and Palos Verdes faults. Of these, the Newport-Inglewood fault zone extends through the southwestern portion of Newport Beach (see Map 6.1), whereas the Whittier fault, although not extending through the city is sufficiently close to still cause extensive damage in Newport Beach. Seismologists are in agreement that a magnitude 6.0 to 6.5 earthquake on the Newport-Inglewood fault has the potential to cause more damage and casualties than a "great" quake on the San Andreas fault, because the San Andreas fault is farther away from the urban centers of southern California. There are also several "blind" faults that underlie southern California. ["Blind" faults do not break the surface, but rather occur thousands of feet below the ground. They are not less of a seismic hazard, though.] Newport Beach is underlain by one of these "blind" faults, namely, the San Joaquin Hills fault.

Map 6-1: Faults In and Near Newport Beach



Modified from: Shaw et al., 2002; Dolan, Shaw, and Pratt, 2001; and Jennings, 1995

Map Explanation

-  Blind thrust fault ramp; red hatchures show surface projection or upper edge of thrust ramp, the thrust fault ramps are shown from deepest to shallowest by gray and green shading, respectively.
-  Fault Showing Evidence of Historic Rupture (Active).
-  Fault Showing Evidence of Holocene Rupture (Active).
-  Fault Showing Evidence of Quaternary and Late Quaternary Rupture (Potentially Active).

Although great advances in earthquake engineering have been made in the last two decades, in great part as a result of the lessons learned from the 1994 Northridge, California, 1995 Kobe, Japan, 1999 Izmit, Turkey and 1999 Chi-Chi, Taiwan earthquakes, the majority of California communities remain unprepared because there is a general lack of understanding regarding earthquake hazards among Californians. Yet, although it is not possible to prevent earthquakes, their destructive effects can be minimized. Comprehensive hazard mitigation programs that include the identification and mapping of hazards, prudent planning, public education, emergency exercises, enforcement of building codes, and expedient retrofitting and rehabilitation of weak structures can significantly reduce the scope of an earthquake’s effects and avoid disaster. Local governments, emergency relief organizations, and residents must take action to develop and implement policies and programs to reduce the effects of earthquakes.

Earthquake Basics - Definitions

The outer 10 to 70 kilometers of the Earth consist of enormous blocks of moving rock, called **plates**. There are about a dozen major plates, which slowly collide, separate, and grind past each other. In the uppermost plates, friction locks the plate edges together, while movement continues at depth. Consequently, the near-surface rocks bend and deform near plate boundaries, storing strain energy. Eventually, the frictional forces are overcome and the locked portions of the plates move. The stored strain energy is released in waves.

By definition, the break or fracture between moving blocks of rock is called a **fault**, and such differential movement produces a **fault rupture**. The place where the fault first ruptures is called the **focus** (or **hypocenter**). The released energy waves radiate out in all directions from the rupture surface, making the earth vibrate and shake as the waves travel through. This shaking is what we feel in an **earthquake**.

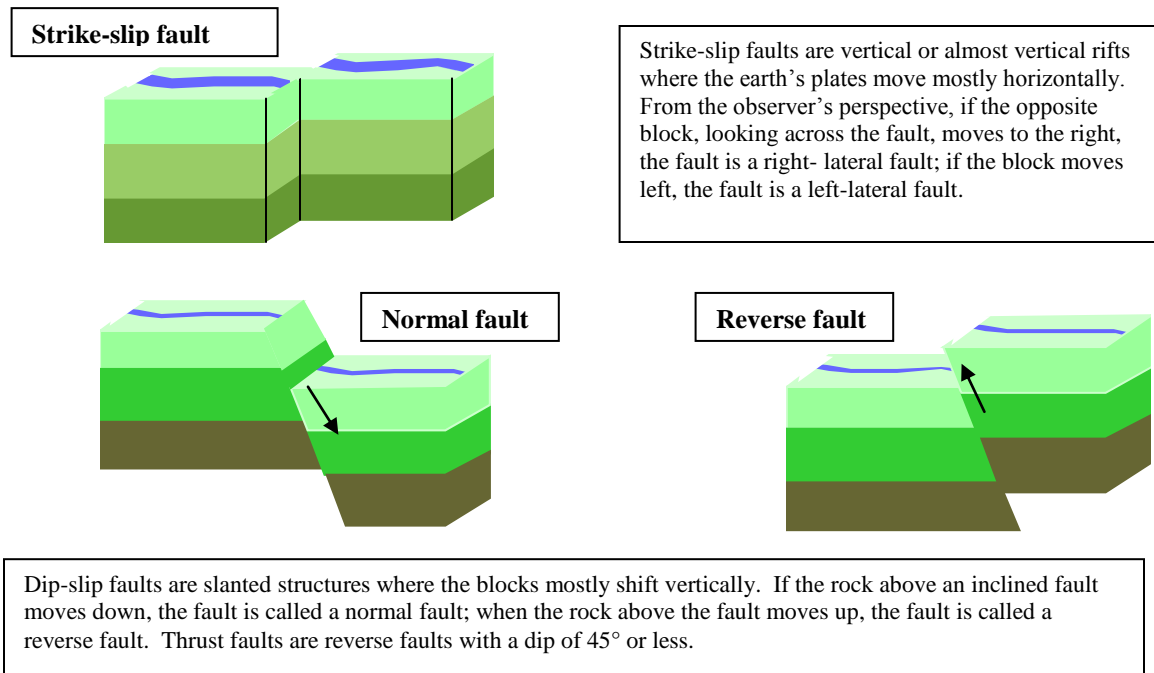
Although earthquakes can occur in areas with no known faults, most earthquakes occur on or near plate boundaries. Given that California straddles the boundary between the North American and Pacific plates, it experiences many earthquakes, and relatively often. The Pacific Plate is moving northwesterly, relative to the North American Plate, at about 50 mm/yr. This is about the rate at which fingernails grow, and seems unimpressive. However, it is enough to accumulate enormous amounts of strain energy over dozens to thousands of years. Despite being locked in place most of the time, in another 15 million years (a short time in the context of the Earth's history), due to plate movements, Newport Beach will be hundreds of kilometers north of San Francisco.

Although the San Andreas fault marks the actual separation between the Pacific and North American plates, only about 70 percent of the plate motion occurs on the San Andreas fault itself. The rest is distributed among other faults of the San Andreas system, including the San Jacinto, Whittier-Elsinore, Newport-Inglewood, Palos Verdes, plus several offshore faults; and among faults of the Eastern Mojave Shear Zone, a series of faults east of the San Andreas fault, that were responsible for the 1992 Landers and 1999 Hector Mine earthquakes. Thus, the zone of plate-boundary earthquakes and ground deformation covers an area that stretches from the Pacific Ocean to Nevada.

Because the Pacific and North American plates are sliding past each other, with relative motions to the northwest and southeast, respectively, all of the faults mentioned above are aligned northwest-southeast, and are **strike-slip faults** (see Figure 6-1). On average, strike-slip faults are nearly vertical breaks in the rock, and when a strike-slip fault ruptures, the rocks on either side of the fault slide horizontally past each other.

However, about 75 miles northeast of Newport Beach, there is a kink in the San Andreas fault, commonly referred to as the "Big Bend." Near the Big Bend, the two plates do not slide past each other. Instead, they collide, causing localized compression, resulting in folding and **thrust faulting** (see Figure 6-1). Thrust faults meet the surface of the Earth at a low angle, dipping 25 to 45 degrees from the horizontal. Thrusts are a type of **dip-slip fault**, where rocks on opposite sides of the fault move up or down relative to each other. When a thrust fault ruptures, the top block of rock moves up and over the rock on the other side of the fault.

Figure 6-1: Main Types of Faults



Few faults are simple, planar breaks in the Earth. They more often consist of smaller **strands**, with a similar orientation and sense of movement. Sometimes geologists group strands into **sections** or **segments**, which are believed capable of rupturing together during a single earthquake. The more extensive the fault, the bigger the earthquake it can produce. Therefore, multi-strand fault ruptures generally produce larger earthquakes.

Large-magnitude earthquakes that occur near urban centers have the potential to cause the most damage. Thus, fault dimensions and proximity to urban centers are key parameters in any hazard assessment. In addition, it is important to know a fault's style of movement (i.e. is it dip-slip or strike-slip), the age of its most recent activity, its total displacement, and its slip rate (all discussed below). These values are helpful in estimating how often a fault produces damaging earthquakes, and the size of the earthquake that will be generated the next time that fault ruptures.

Total displacement is the length, measured in kilometers (km), of the total movement that has occurred along the fault over as long a time as the geologic record reveals. It is usually estimated by measuring the distance between geologic features (such as a distinctive rock formation) that have been split apart and separated (**offset**) by the cumulative movement of the fault over many earthquakes. **Slip rate** is a speed, expressed in millimeters per year (mm/yr). Slip rate is estimated by measuring an amount of offset accrued during a known amount of time, obtained by dating the ages of geologic features. Slip rate data also are used to estimate a fault's **earthquake recurrence interval**. Sometimes referred to as "repeat time" or "return interval," the recurrence interval represents the average amount of time that elapses between major earthquakes on a fault. Geologists generally derive the recurrence interval for a fault by excavating a series of trenches across the fault to obtain **paleoseismic** evidence of the earthquakes that have occurred during prehistoric time. If the sediments exposed in the trenches are suitable for dating and the earthquake record is well preserved, geologists can date (typically with a certain margin of error)

the past earthquakes, and from that data, develop an average earthquake recurrence interval for that fault segment.

In southern California, ruptures along thrust faults have built the Transverse Ranges geologic province, a region with an east-west trend to its landforms and underlying geologic structures. This orientation is anomalous, virtually unique in the western United States, and a direct consequence of the plates colliding at the Big Bend. Many of southern California's most recent damaging earthquakes have occurred on thrust faults that are uplifting the Transverse Ranges, including the 1971 San Fernando, the 1987 Whittier Narrows, the 1991 Sierra Madre, and the 1994 Northridge earthquakes. In addition to generating stronger ground shaking than a similar-magnitude earthquake on a strike-slip fault, thrust faults are also particularly hazardous because many are **blind**, that is, they do not extend to the surface of the Earth. These blind thrust faults are extremely difficult to detect before they rupture. Some of the most recent earthquakes, like the 1987 Whittier Narrows earthquake, and the 1994 Northridge earthquake, occurred on blind thrust faults.

When comparing the sizes of earthquakes, the most meaningful feature is the amount of energy released. Thus scientists most often consider **seismic moment**, a measure of the energy released when a fault ruptures. We are more familiar, however, with scales of **magnitude**, which measure amplitude of ground motion. Magnitude scales are logarithmic. Each one-point increase in magnitude represents a ten-fold increase in amplitude of the waves as measured at a specific location, and a 32-fold increase in energy. That is, a magnitude 7 earthquake produces 100 times (10×10) the ground motion amplitude of a magnitude 5 earthquake. Similarly, a magnitude 7 earthquake releases approximately 1,000 times more energy (32×32) than a magnitude 5 earthquake. Scientists now use the **moment magnitude (M_w)** scale to relate energy release to magnitude; this scale has replaced the Richter scale, which is no longer used by seismologists.

An early measure of earthquake size still used today is the seismic **intensity scale**, which is a qualitative assessment of an earthquake's effects at a given location. Although it has limited scientific application, intensity is still widely used because it is intuitively clear and quick to determine. The most commonly used measure of seismic intensity is called the Modified Mercalli Intensity (MMI) scale, which has 12 levels of damage (see Table 6-1).

A given earthquake will have one moment and, in principle, one magnitude, although there are several methods of calculating magnitude, which give slightly different results. However, one earthquake will produce many intensities because intensity effects vary with the location (distance), soil conditions, and perceptions of the observer.

Table 6-1: Abridged Modified Mercalli Intensity Scale

Intensity Value and Description		Average Peak Velocity (cm/sec)	Average Peak Acceleration (g = gravity)
I.	Not felt except by a very few under especially favorable circumstances (I Rossi-Forel scale). Damage potential: None.	<0.1	<0.0017
II.	Felt only by a few persons at rest, especially on upper floors of high-rise buildings. Delicately suspended objects may swing. (I to II Rossi-Forel scale). Damage potential: None.	0.1 – 1.1	0.0017 – 0.014
III.	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing automobiles may rock slightly. Vibration like passing of truck. Duration estimated. (III Rossi-Forel scale). Damage potential: None.		
IV.	During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make creaking sound. Sensation like a heavy truck striking building. Standing automobiles rocked noticeably. (IV to V Rossi-Forel scale). Damage potential: None. Perceived shaking: Light.	1.1 – 3.4	0.014 - 0.039
V.	Felt by nearly everyone; many awakened. Some dishes, windows, and so on broken; cracked plaster in a few places; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop. (V to VI Rossi-Forel scale). Damage potential: Very light. Perceived shaking: Moderate.	3.4 – 8.1	0.039-0.092
VI.	Felt by all; many frightened and run outdoors. Some heavy furniture moved, few instances of fallen plaster and damaged chimneys. Damage slight. (VI to VII Rossi-Forel scale). Damage potential: Light. Perceived shaking: Strong.	8.1 - 16	0.092 -0.18
VII.	Everybody runs outdoors. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving cars. (VIII Rossi-Forel scale). Damage potential: Moderate. Perceived shaking: Very strong.	16 - 31	0.18 - 0.34
VIII.	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, and walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving cars disturbed. (VIII+ to IX Rossi-Forel scale). Damage potential: Moderate to heavy. Perceived shaking: Severe.	31 - 60	0.34 - 0.65
IX.	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken. (IX+ Rossi-Forel scale). Damage potential: Heavy. Perceived shaking: Violent.	60 - 116	0.65 – 1.24
X.	Some well-built wooden structures destroyed; most masonry and frame structures destroyed; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed, slopped over banks. (X Rossi-Forel scale). Damage potential: Very heavy. Perceived shaking: Extreme.	> 116	> 1.24
XI.	Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.		
XII.	Damage total. Waves seen on ground surface. Lines of sight and level distorted. Objects thrown into air.		

Modified from Bolt (1999); Wald et al. (1999).

Causes of Earthquake Damage

Causes of earthquake damage can be categorized into three general areas: strong shaking, various types of ground failure that are a result of shaking, and ground displacement along the rupturing fault.

Ground Shaking

Ground shaking is the motion felt on the earth's surface caused by seismic waves generated by the earthquake. It is the primary cause of earthquake damage, and is typically reported as the peak horizontal ground acceleration estimated as a percentage of **g**, the acceleration of gravity. Full characterization of shaking potential, though, requires estimates of peak (maximum) ground displacement and velocity, the duration of strong shaking, and the periods (lengths) of waves that will control each of these factors at a given location. The strength of ground shaking also depends on the source, path, and site effects. Estimates of the ground shaking that different locations in California are likely to experience have been mapped, as shown on Map 6-2.

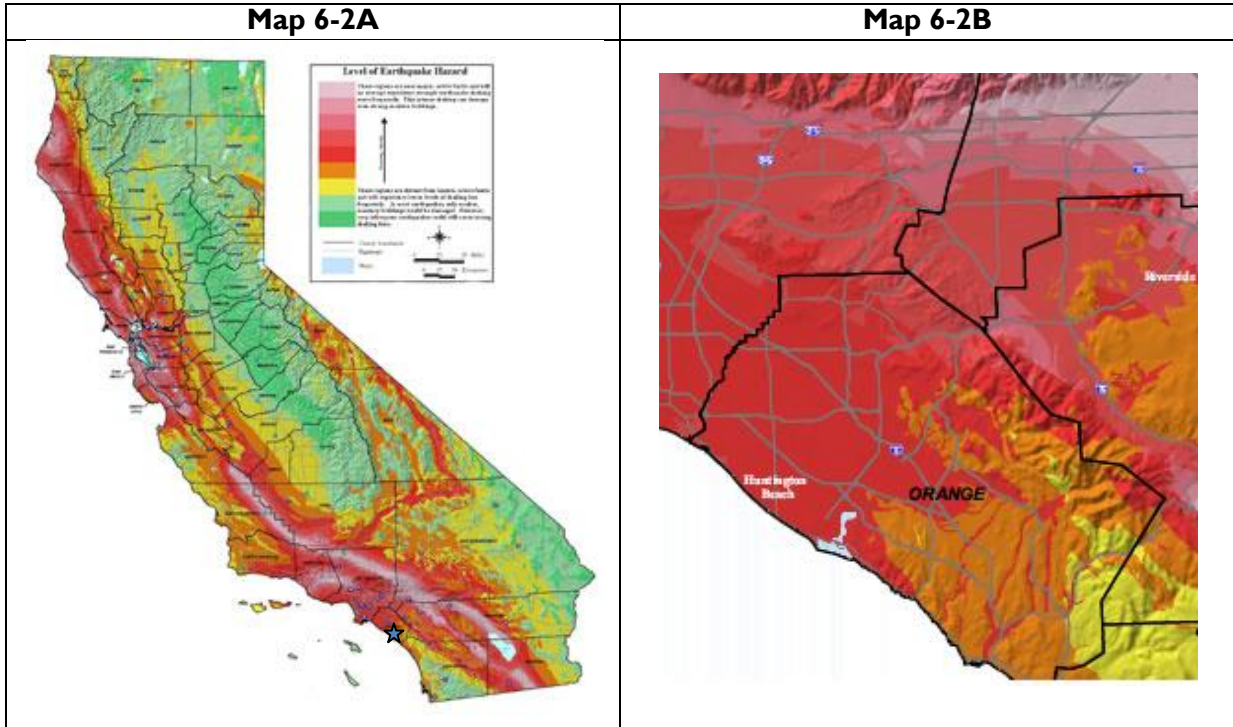
- **Source effects** include earthquake size, location, and distance, plus directivity of the seismic waves (for example, the 1995, M_w 6.9, Kobe, Japan earthquake was not much bigger than the 1994, M_w 6.7 Northridge, California earthquake, but Kobe caused much worse damage. During the Kobe earthquake, the fault's orientation and movement directed seismic waves into the city, whereas during the Northridge earthquake, the fault's motion directed waves away from populous areas.
- **Path effects** refer to how the seismic waves change direction as they travel through the Earth's contrasting layers, just as light bounces (reflects) and bends (refracts) as it moves from air to water. Sometimes seismic energy gets focused into one location and causes damage in unexpected areas (focusing of the seismic waves generated by the 1989 M_w 7.1 Loma Prieta earthquake caused damage in San Francisco's Marina district, some 100 km distant from the rupturing fault).
- **Site effects** refer to how seismic waves interact with the ground surface. Seismic waves slow down in the loose sediments and weathered rock at the Earth's surface; as they slow, their energy converts from speed to amplitude, which heightens shaking (amplification). Therefore, buildings on poorly consolidated and thick soils will typically see more damage than buildings on consolidated soils and bedrock. Amplification can also occur in areas on deep, sediment-filled basins and on ridge tops. Seismic waves can also get trapped at the surface and reverberate (resonate). Whether resonance will occur depends on the period (the length) of the incoming waves – long-period seismic waves, which are created by large earthquakes, are most likely to reverberate and cause damage in long-period structures, like bridges and high-rises. (“Long-period structures” are those that respond to long-period waves.) Shorter-period seismic waves, which tend to die out quickly, will most often cause damage fairly near the fault, and they will cause most damage in shorter-period structures such as one- to three-story buildings. Very short-period waves are most likely to cause near-fault, interior damage, such as to equipment.

Earthquake damage also depends on the characteristics of human-made structures. The interaction of ground motion with the built environment is complex. Governing factors include a structure's height, construction, and stiffness, architectural design, condition, and age.

Map 6-2A: Ground Shaking Zones in California

Map 6-2B: Ground Shaking Zones in Orange County and Surrounding Areas

(Maps show the level of ground shaking with a 10 percent chance of exceedance in 50 years – the pink and red zones can experience higher ground shaking because they are closer to active faults. The blue star in Map 6-2A shows the approximate location of Newport Beach).



Source: <http://www.consrv.ca.gov/cgs/rghm/psha/Pages/index.aspx>

Liquefaction

Liquefaction typically occurs within the upper 50 feet of the surface, where saturated, loose, fine- to medium-grained soils (sand and silt) are present. Earthquake shaking suddenly increases pressure in the water that fills the pores between soil grains, causing the soil to lose strength and behave as a liquid. This process can be observed at the beach by standing on the wet sand near the surf zone. Standing still, the sand will support your weight. However, when you tap the sand with your feet, water comes to the surface, the sand liquefies, and your feet sink.

Liquefaction-related effects include loss of bearing strength, ground oscillations, lateral spreading and flow failures or slumping. The excess water pressure is relieved by the ejection of material upward through fissures and cracks. When soils liquefy, the structures built on them can sink, tilt, and suffer significant structural damage. Buildings and their occupants are at risk when the ground can no longer support the buildings.

Earthquake-Induced Landslides and Rockfalls

Earthquake-induced landslides and rockfalls are secondary earthquake hazards that occur from ground shaking. Gravity inexorably pulls hillsides down, and earthquake shaking enhances this on-going process. Landslides and rockfalls can destroy roads, buildings, utilities, and other critical facilities necessary to respond and recover from an earthquake. Many communities in southern

California with steep slopes have a high likelihood of being impacted by earthquake-induced landslides or rockfalls.

Fault Rupture

Primary ground rupture due to fault movement typically results in a relatively small percentage of the total damage in an earthquake, yet being too close to a rupturing fault can result in extensive damage. It is difficult to safely reduce the effects of this hazard through building and foundation design. Therefore, the primary mitigation measure is to avoid active faults by setting structures back from the fault zone. Application of this measure is subject to the requirements of the Alquist-Priolo Earthquake Fault Zoning Act and guidelines established by the California Geological Survey – previously known as the California Division of Mines and Geology – and the State Mining and Geology Board.

History of Earthquake Events in Southern California

To better understand earthquake hazards, scientists study past earthquakes by looking at their records, and by studying the effects that past earthquakes had on the ground surface and the built environment. Historical earthquake records are either from the instrumental period (since about 1932, when the first seismographs were deployed), or pre-instrumental. In the absence of instrumentation, the detection and record of earthquakes are based on observations and felt reports, and are dependent upon population density and distribution. Since California was sparsely populated in the 1800s, our record of pre-instrumental earthquakes is relatively incomplete. However, two very large earthquakes, the Fort Tejon in 1857 (M7.9) and the Owens Valley in 1872 (M7.6), are evidence of the tremendously damaging potential of earthquakes in southern California. More recently, two M7.3 earthquakes struck southern California, in Kern County (1952) and Landers (1992), and a M7.1 earthquake struck the Mojave Desert (Hector Mine, in 1999). The damage from these five large earthquakes was limited because they occurred in sparsely populated areas. A similarly sized earthquake closer to southern California's population centers has the potential to place millions of people at risk.

Since seismologists started recording and measuring earthquakes, there have been tens of thousands of recorded earthquakes in southern California, most with a magnitude below 3.0. These recordings show that only the easternmost portion of southern California may be beyond the reach of a damaging earthquake (see Map 6-2). Table 6-2 lists the moderate to large historical earthquake events that have affected southern California. The most significant of these events, either because they were felt strongly in the Newport Beach area, or because they led to the passage of important legislation, are summarized below. Map 6-3 shows the historical seismicity in the immediate vicinity of Newport Beach. The map shows that small earthquakes, of magnitude between 1 and 3, have occurred historically in the area, but, except for the 1933 earthquake, no other moderate to large earthquakes have occurred beneath Newport Beach in historical times.

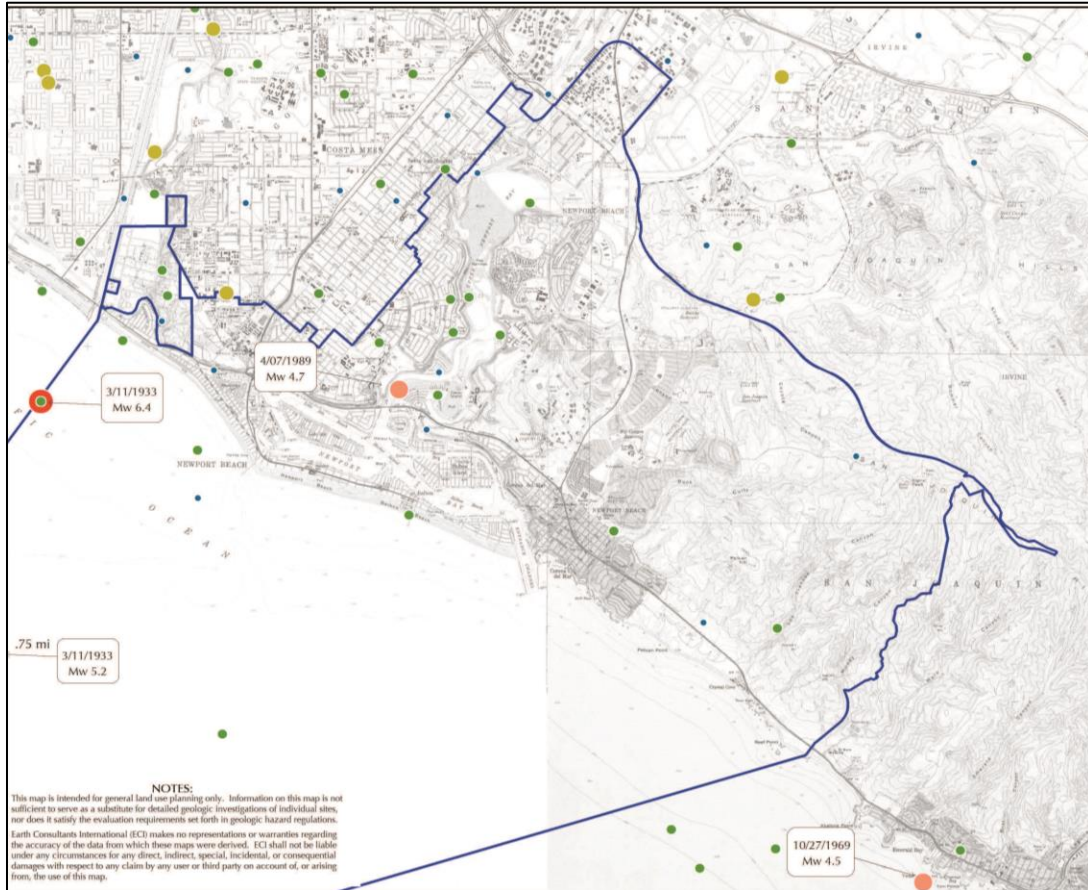
Table 6-2: Historical (1769 – March 2014) Earthquakes in the Southern California Region with Magnitudes > 5.0

1769	Orange County - Los Angeles Basin	1941	Wilmington
1800	San Diego Region	1943	Big Bear Lake Region
1812	Wrightwood	1944	Desert Hot Springs – Cabazon Region
1812	Santa Barbara Channel	1947	Desert Hot Springs – Yucca Valley Region
1827	Los Angeles Region, offshore Malibu	1951	San Clemente Island
1852	Fort Tejon area, east of Lebec	1952	Tehachapi, Kern County Region
1855	Los Angeles Region	1952	Tehachapi aftershocks
1857	Great Fort Tejon Earthquake	1954	West of Wheeler Ridge
1858	San Bernardino Region	1968	Near Santa Cruz Island
1862	San Diego Region	1969	Offshore San Nicolas Island
1880	Moreno Valley – Perris Region	1970	Lytle Creek, east of Mount Baldy
1883	West of Frazier Park	1971	San Fernando
1889	Mountains north of Morongo Valley	1971	San Fernando aftershocks
1892	San Jacinto or Elsinore Fault	1973	Point Mugu
1893	Pico Canyon	1978	Offshore Santa Barbara
1894	Lytle Creek Region	1981	Offshore, Channel Islands Region
1894	San Diego Region	1986	North Palm Springs
1899	Lytle Creek region	1987	Whittier Narrows
1899	San Jacinto and Hemet	1987	Whittier Narrows aftershock
1899	San Jacinto and Hemet aftershocks	1988	Between Lebec and Tehachapi
1905	San Bernardino Region	1990	Claremont area
1907	San Bernardino Region	1991	North of Pasadena
1910	Glen Ivy Hot Springs	1992	Landers
1912	Offshore, west of Malibu	1992-199	Landers aftershocks
1916	Tejon Pass Region	1992	Big Bear
1918	San Jacinto	1994	Northridge
1923	San Bernardino Region	1994	Northridge aftershocks
1925	Santa Barbara	1997	West of Santa Clarita
1925	Santa Barbara aftershocks	1999	Hector Mine
1926	Mountains north of Carpinteria	1999	Hector Mine aftershocks
1930	Offshore Malibu	2005	Southeast of Anza
1930	Seven Oaks Dam area, two events	2005	South shores of Salton Sea
1933	Long Beach	2008	Chino Hills
1933	Long Beach aftershocks	2010	Baja California, South of Mexicali
1935	Mountains north of Morongo Valley	2010	Baja California aftershocks
1938	Santa Ana Mountains	2010	Northwest of Borrego Springs
1940	Mountains north of Northridge	2012	North of Brawley
1941	Carpinteria and Santa Barbara	2012	North of Brawley
1941	Lebec	2014	La Habra

Map 6-3: Historical Seismicity in Newport Beach (1855- March 2014)

(Blue circles represent earthquakes of magnitude 1-2; green circles represent earthquakes of magnitude 2-3; yellow circles are magnitude 3-4 earthquakes; orange circles are magnitude 4-5 earthquakes; and red circle shows epicenter of 1933 M_w 6.4 earthquake.

For a larger version of this map, refer to Plate H-2 in Appendix H.)



Unnamed Earthquake of 1769

On July 28, 1769 the first recorded earthquake in southern California was noted by the Spanish explorers traveling north with Gaspar de Portolá. At the time of the earthquake, the explorers were camped about 10 miles north of present-day Newport Beach, on the east bank of the Santa Ana River. Father Juan Crespo, who kept a daily account of the expedition, reported a strong mainshock followed by five days of moderate aftershocks; an estimated magnitude of at least 6.0 has been assigned to the event based on the explorers' account (Teggart, 1911). The source for this earthquake is unknown, and is still being debated by the paleoseismology community. Some researchers have suggested that this earthquake, of possible magnitude 7.3, may have caused coastal uplift in the northern Orange County region, with the causative fault being the blind thrust under the San Joaquin Hills (Grant et al., 2002). The nearby Elsinore and Newport-Inglewood faults are also considered possible sources for this earthquake.

Unnamed Earthquake of 1800

An earthquake with an estimated magnitude of 6.5 occurred on November 22, 1800 in the coastal region of southern California. Based on the distribution of damage attributed to the earthquake, the epicenter is thought to have been between Newport Beach and San Diego, and was possibly located

offshore (Ellsworth, 1990). The earthquake damaged the mission at San Juan Capistrano, located less than 20 miles from present-day Newport Beach and collapsed a barracks in San Diego (www.sfmuseum.org/alm/quakeso.html).

Wrightwood Earthquake of December 12, 1812

This large earthquake occurred on December 8, 1812 and was felt throughout southern California. Based on accounts of damage recorded at missions in the earthquake-affected area, an estimated magnitude of 7.5 has been calculated for the event (Topozada et al., 1981). Subsurface investigations and tree ring studies show that the earthquake likely ruptured the Mojave section of the San Andreas fault near Wrightwood, and may have been accompanied by a significant surface rupture between Cajon Pass and Tejon Pass (Jacoby, Sheppard and Sieh, 1988; www.scecdc.scec.org/quakedex.html). The worst damage caused by the earthquake occurred significantly west of the San Andreas fault at San Juan Capistrano Mission, where the roof of the church collapsed, killing 40 people. The earthquake also damaged walls and destroyed statues at San Gabriel Mission and damaged missions in the Santa Barbara area. Strong aftershocks caused earthquake-damaged buildings to collapse for several days after the mainshock.

Unnamed Earthquake of December 21, 1812

The Wrightwood earthquake was followed by a strong earthquake on December 21st that caused widespread damage in the Santa Barbara area. The effects of this second earthquake are sometimes attributed to the December 12th event, giving the impression that a single large earthquake caused significant damage from Santa Barbara to San Diego. The second earthquake had an estimated magnitude 7 and was likely located offshore, within the Santa Barbara Channel, although it may have occurred inland, in Santa Barbara or Ventura counties (www.scecdc.scec.org/quakedex.html). The earthquake destroyed the church at the Mission in Santa Barbara, the Mission of Purísima Concepción near present-day Lompoc, and the Mission at Santa Inéz (www.johnmartin.com/eqs/00000077.htm). The earthquake also caused a tsunami that may have traveled up to 1/2 mile inland near Santa Barbara (see Section on Flood Hazards).

Unnamed Earthquake of 1855

This earthquake occurred on July 11, 1855 and was felt across southern California from Santa Barbara to San Bernardino. Light to moderate damage was reported in the Los Angeles area, where 26 houses experienced cracked walls and the bell tower of the San Gabriel Mission was knocked down (www.sfmuseum.org/alm/quakeso.html). Because damage was limited primarily to the Los Angeles area, this earthquake is postulated to have occurred on a local fault such as the Hollywood, Raymond, Whittier or Newport-Inglewood faults, or on one of the many blind thrust faults that underlie this area.

San Jacinto Earthquake of 1899

This earthquake occurred at 4:25 in the morning on Christmas Day, in 1899. The main shock is estimated to have had a magnitude of 6.5. Several smaller aftershocks followed the main shock, and in the town of San Jacinto, as many as thirty smaller tremors were felt throughout the day. The epicenter of this earthquake is not well located, but damage patterns suggest it occurred near the town of San Jacinto, with the causative fault most likely being the San Jacinto fault. Both the towns of San Jacinto and Hemet reported extensive damage, with nearly all brick buildings either badly damaged or destroyed. Six people were killed in the Soboba Indian Reservation as a result of falling adobe walls. In Riverside, chimneys toppled and walls cracked (Claypole, 1900). The main earthquake was felt over a broad area that included San Diego to the southwest, Needles to the northeast, and Arizona to the east. No surface rupture was reported, but several large “sinks” or subsidence areas were reported about 10 miles to the southeast of San Jacinto.

Elsinore Earthquake of 1910

This magnitude 6 earthquake occurred on May 15, 1910 at 7:47 A.M. Pacific Standard Time, following two moderate tremors that occurred on April 10 and May 12, 1910. The Glen Ivy North section of the Elsinore fault is thought to have caused the earthquake, although no surface rupture along this fault was reported at the time. Damage as a result of this earthquake was minor; toppled chimneys were reported in the Corona, Temescal and Wildomar areas, and a 14-inch offset in a cement flume is also attributed to this event (Brake, 1987; Rockwell and Brake, 1987). The epicentral location of this earthquake is very poorly defined, a direct result of the area being scarcely populated.

San Jacinto Earthquake of 1918

The magnitude 6.8 San Jacinto earthquake occurred on April 21, 1918 at 2:32 P.M. Pacific Standard Time, near the town of San Jacinto. The earthquake caused extensive damage to the business districts of San Jacinto and Hemet, where many masonry structures collapsed, but because it occurred on a Sunday, when these businesses were closed, the number of fatalities and injuries was low. Several people were injured, but only one death was reported. Minor damage as a result of this earthquake was reported outside the San Jacinto area, and the earthquake was felt as far away as Taft (west of Bakersfield), Seligman (Arizona), and Baja California.

Long Beach Earthquake of 1933

This M_w 6.4 earthquake occurred on March 10, 1933, at 5:54 in the afternoon, following a strong foreshock the day before. The location of the earthquake's epicenter has been re-evaluated, and determined to have occurred approximately 3 miles south of present-day Huntington Beach, offshore of Newport Beach (see Map 6.3). However, it caused extensive damage in Long Beach, hence its name. The earthquake occurred on the Newport-Inglewood fault, a right-lateral strike slip fault that extends across the western portion of the Los Angeles basin. The Newport-Inglewood fault did not rupture the surface during this earthquake, but substantial liquefaction-induced damage was reported. The earthquake caused 120 deaths, and over \$50 million in property damage (Wood, 1933). In the Newport Beach area, the earthquake produced Modified Mercalli Intensities of VII-VIII (<http://pasadena.wr.usgs.gov/shake/ca/>). Many strong aftershocks occurred through March 16th.

Although primary ground rupture of the Newport-Inglewood fault was not observed, secondary cracking, minor slumping, and lateral movement of unconsolidated sediments occurred throughout the region. Road surfaces along the shore between Long Beach and Newport Beach were damaged by settlement of road fills that had been placed on marshy land. In urban areas, unreinforced masonry buildings were most severely damaged, especially in areas of artificial fill or water-soaked alluvium. In one part of Compton, most buildings built on unconsolidated sediments and artificial fill were destroyed. In Long Beach, many buildings collapsed, were pushed off their foundations, or had walls or chimneys knocked down. In Newport Beach, 800 chimneys were knocked down at the roofline and hundreds of houses were destroyed (www.anaheimcocom.com/quake.htm). As a result, building codes were improved. Damage to school buildings was especially severe; fortunately, children were not present in the classrooms at that time, otherwise, the death toll would have been much higher. This earthquake led to the passage of the Field and Riley Acts by the State legislature. The Field Act regulates school construction, and gives the Division of the State Architect authority and responsibility for approving the design and supervising the construction of public schools. The Riley Act regulates the construction of buildings larger than two-family dwellings.

Torrance-Gardena Earthquakes of 1941

In 1941, two small earthquakes struck the southern Los Angeles basin, affecting surrounding communities. Although these earthquakes were relatively minor, they occurred close to the surface

and caused significant, although localized damage. The magnitude 4.8 Torrance earthquake occurred on October 21st at 10:57 P.M., Pacific Standard Time and was located east of Carson, near the present-day interchange of the 405 and 710 freeways. Shaking up to intensity level VII was reported in the communities of Wilmington, Gardena, Lynwood, Hynes and Signal Hill where walls were cracked and chimneys damaged. In some cases, houses that had not been adequately repaired after the 1933 Long Beach earthquake were damaged again. No injuries were reported and damage estimates totaled \$100,000 (www.scecdc.scec.org/quakedex.html).

A second earthquake occurred less than a month later, on November 14 at 12:42 A.M. Pacific Standard Time, near Wilmington. Shaking during the second earthquake was reportedly stronger than the first, locally reaching intensity level VIII (Table 6-1) and felt as far away as Cabazon, Carpinteria, and San Diego. Gas and water mains burst near the epicenter and storefronts in the business districts of Torrance and Gardena collapsed, crushing parked cars. Damage to local oilfields was significant - well casings and equipment were damaged and a 55,000 gallon oil tank ruptured, flooding nearby streets with oil. Production of several wells was lowered or stopped. No injuries were reported, although damage attributed to the second event totaled one million dollars (www.scecdc.scec.org/quakedex.html).

San Fernando (Sylmar) Earthquake of 1971

This M_w 6.6 earthquake occurred on the San Fernando fault zone, the western-most segment of the Sierra Madre fault, on February 9, 1971, at 6:00 in the morning. The surface rupture caused by this earthquake was nearly 12 miles long, and occurred in the Sylmar-San Fernando area, approximately 55 miles (88 km) northwest of Newport Beach. The maximum slip measured at the surface was nearly 6 feet.

The earthquake caused over \$500 million in property damage and 65 deaths. Most of the deaths occurred when the Veteran's Administration Hospital collapsed. Several other hospitals, including the Olive View Community Hospital in Sylmar suffered severe damage. Newly constructed freeway overpasses also collapsed, in damage scenes similar to those that occurred 23 years later during the 1994 Northridge earthquake. Loss of life could have been much greater had the earthquake struck at a busier time of day. As with the Long Beach earthquake, legislation was passed in response to the damage caused by the 1971 earthquake. In this case, the building codes were strengthened and the Alquist Priolo Special Studies (now Earthquake Fault Zone) Act was passed in 1972.

Oceanside Earthquake of 1986

This magnitude 5.4 earthquake occurred on the morning of July 13, 1986 at 6:47 A.M. Pacific Daylight Time. The epicenter was about 32 miles offshore Oceanside and occurred on an unidentified fault that may be related to the San Diego Trough or the Palos Verdes-Coronado Bank fault zones (www.scecdc.scec.org/quakedex.html). One death and at least 29 injuries are attributed to this relatively small earthquake, which was felt throughout the coastal communities of southern California. At least 50 buildings were damaged from Newport Beach to San Diego, with damage estimates totaling nearly one million dollars.

Whittier Narrows Earthquake of 1987

The Whittier Narrows earthquake occurred on October 1, 1987, at 7:42 in the morning, with its epicenter located approximately 27 miles (43 km) northwest of Newport Beach (Hauksson and Jones, 1989). This magnitude 5.9 earthquake occurred on a previously unknown, north-dipping concealed thrust fault (blind thrust) now called the Puente Hills fault (Shaw and Shearer, 1999). The earthquake caused eight fatalities, over 900 injured, and \$358 million in property damage. Severe damage was confined mainly to communities east of Los Angeles and near the epicenter. Areas with

high concentrations of unreinforced masonry (URM) buildings, such as the “uptown” district of Whittier, the old downtown section of Alhambra, and the “Old Town” section of Pasadena, were severely impacted. Several tilt-up buildings partially collapsed, including tilt-up buildings built after 1971, that were built to meet improved building standards, but were of irregular configuration, revealing seismic vulnerabilities not previously recognized. Residences that sustained damage usually were constructed of masonry, were not fully anchored to their foundations, or were houses built over garages with large openings. Many chimneys collapsed and in some cases, fell through roofs. Wood-frame residences, in contrast, sustained relatively little damage, and no severe structural damage to high-rise structures in downtown Los Angeles was reported.

Newport Beach Earthquake of 1989

A small, magnitude 4.7 earthquake struck the city of Newport Beach at 1:07 P.M. Pacific Daylight Time on April 7, 1989 (www.scecdc.scec.org/quakedex.html). The earthquake did not rupture the surface or cause any significant damage, but is notable because it occurred on the Newport-Inglewood fault system directly below the city of Newport Beach (see Map 6-3).

Landers and Big Bear Earthquakes of 1992

On the morning of June 28, 1992, most people in southern California were awakened at 4:57 by the largest earthquake to strike California in 40 years. Named “Landers” after a small desert community near its epicenter, the earthquake had a magnitude of 7.3. Centered in the Mojave Desert, approximately 120 miles from Los Angeles, the earthquake caused relatively little damage for its size (Brewer, 1992). It released about four times as much energy as the very destructive Loma Prieta earthquake of 1989, but fortunately, it did not claim as many lives (one child died when a chimney collapsed). The power of the earthquake was illustrated by the length of the ground rupture it left behind. More than 50 miles of surface rupture occurred as a result of this earthquake. The earthquake ruptured five separate faults: Johnson Valley, Landers, Homestead Valley, Emerson, and Camp Rock faults (Sieh et al., 1993). Other nearby faults also experienced triggered slip and minor surface rupture. The average right-lateral strike-slip displacement was about 10 to 15 feet, with a maximum of up to 18 feet observed. Modified Mercalli Intensities of III were reported in the Newport Beach area as a result of this earthquake (<http://pasadena.wr.usgs.gov/shake/ca/>).

The magnitude 6.4 Big Bear earthquake struck little more than 3 hours after the Landers earthquake on June 28, 1992 at 8:05:30 A.M. PDT. This earthquake is technically considered an aftershock of the Landers earthquake (indeed, the largest aftershock), although the Big Bear earthquake occurred over 20 miles west of the Landers rupture, on a fault with a different orientation and sense of slip than those involved in the main shock. From its aftershock, the causative fault was determined to be a northeast-trending left-lateral fault. This orientation and slip are considered “conjugate” to the faults that slipped in the Landers rupture. The Big Bear earthquake did not break the ground surface, and, in fact, no surface trace of a fault with the proper orientation has been found in the area. The Big Bear earthquake caused a substantial amount of damage in the Big Bear area, but fortunately, it claimed no lives. However, landslides were triggered by the quake blocked roads in the mountainous areas, aggravating the clean-up and rebuilding process (www.scecdc.scec.org/quakedex.html).

Northridge Earthquake of 1994

The Northridge Earthquake of January 17, 1994 woke up most of southern California at 4:30 in the morning. The earthquake’s epicenter was located 20 miles to the west-northwest of downtown Los Angeles, on a previously unknown blind thrust fault now called the Northridge (or Pico) Thrust. Although moderate in size, this earthquake produced the strongest ground motions ever instrumentally recorded in North America. The M_w 6.7 earthquake is one of the most expensive natural disasters to have impacted the United States. Damage was widespread, sections of major

freeways collapsed, parking structures and office buildings collapsed, and numerous apartment buildings suffered irreparable damage. Damage to wood-frame apartment houses was very widespread in the San Fernando Valley and Santa Monica areas, especially to structures with "soft" first floor or lower-level parking garages. The high accelerations, both vertical and horizontal, lifted structures off of their foundations and/or shifted walls laterally. The death toll was 57, and more than 1,500 people were seriously injured. Although most damage was focused in the northern Los Angeles area, intensities of V-VI (Table 6-1) were recorded in the Newport Beach area, causing scattered light to moderate damage. Despite the losses, gains made through earthquake hazard mitigation efforts of the last two decades were obvious. Retrofits of masonry building helped reduce the loss of life, hospitals suffered less structural damage than in 1971 San Fernando earthquake, and emergency response was exemplary.

Hector Mine Earthquake of 1999

Southern California's most recent large earthquake was a widely felt magnitude 7.1. It occurred on October 18, 1999, in a remote region of the Mojave Desert, 47 miles east-southeast of Barstow. Modified Mercalli Intensities of IV (Table 6-1) were reported in the Newport Beach area (<http://pasadena.wr.usgs.gov/shake/ca/>). The Hector Mine earthquake is not considered an aftershock of the M 7.3 Landers earthquake of 1992, although Hector Mine occurred on similar, north-northwest trending strike-slip faults within the Eastern Mojave Shear Zone. Geologists documented a 25-mile (40-km) long surface rupture and a maximum right-lateral strike-slip offset of about 16 feet on the Lavic Lake fault.

Chino Hills Earthquake of 2008

A magnitude 5.4 earthquake occurred in the Chino Hills area south of Diamond Bar on July 29, 2008 at 11:42 AM PDT. The characteristics of the shaking indicate that the earthquake was caused by oblique-reverse faulting, meaning that the motion had components of both thrust and strike-slip. The source of the earthquake, which originated approximately 9 miles (14.5 km) below the ground surface, was assigned to a structure referred to as the "Yorba Linda trend." The shaking was felt throughout the Los Angeles basin, and as far away as San Diego, Tijuana, and Las Vegas, Nevada. Minor structural damage was reported in some of the older buildings at the California State University, Fullerton, and at the Placentia public library.

Baja California Earthquake of 2010

A magnitude 7.2 earthquake that occurred just south of the U.S. - Mexico border on Easter Sunday, April 4, 2010, at 3:40:42 PM PDT, was felt throughout Mexico, southern California, Arizona, and Nevada. Analysis of the waveforms suggests that there were two sub-events, with the first one rupturing an 18-km section of the Pescadores fault, followed, six to 12 seconds later by a second, larger event on the Borrego fault. Both of these faults are part of the Laguna Salada fault system, which is the southern extension of the Elsinore fault. Surface rupture continued northward to just past the border into California. The main earthquake caused triggered slip of up to a few centimeters on several faults in the Salton Sea area, and as far north as in the Mecca Hills. Secondary effects, including liquefaction, rockfalls and shattering were reported along a wide area in the El Centro and Brawley region, and westward toward San Diego. More than 4,000 aftershocks had been recorded ten days after the main shock (<http://www.scsn.org/2010sierraelmayor.html>). A peak instrumental ground acceleration of 1.1g was recorded at the Salton Sea. Similar or stronger shaking may have occurred closer to the epicenter, but given the lack of instrumentation in that area, went unrecorded. Many of the aftershocks occurred along the Elsinore, San Jacinto, and the southern extension of the San Andreas fault through the Brawley area. Based on observations reported by many residents, shaking in the Newport Beach area a result of this earthquake was light, in the Modified Mercalli intensity III to IV range (<http://earthquake.usgs.gov/earthquakes/dyfi/events/ci/14607652/us/index.html>).

La Habra Earthquake of 2014

The magnitude 5.1 earthquake that occurred on Friday, March 28, 2014 at 9:09 PM local time was felt from the Mexican border to the San Joaquin Valley. In Newport Beach, the shaking as a result of this earthquake was reported as weak, consistent with a Modified Mercalli intensity of III. The earthquake, although only moderate in size, caused structural damage to several apartment buildings and a few houses near its epicenter. Water mains and gas lines ruptured in La Habra and Fullerton. As many as 2,000 residents were without power immediately following the earthquake, and approximately 100 customers were still without power almost 24 hours after the temblor. Minor injuries due to broken glass and people trying to leave their residences were reported. The source (fault) for this earthquake is still being investigated by the seismological community; some have suggested the Puente Hills thrust fault, but the northeast trend defined by the hundred plus aftershocks may suggest a previously unknown fault that is somehow related to the Puente Hills thrust fault or the Whittier fault. Additional information regarding the source of this earthquake is anticipated as the seismological community reviews the ground motion data generated by this event.

Earthquake Hazard Assessment

Choosing Earthquakes for Planning and Design

It is often useful to create a **design earthquake scenario** to study the effects of a particular earthquake on a building or a community. Typically, such scenarios have considered the largest earthquake believed possible to occur on a fault or fault segment, referred to as the **maximum magnitude earthquake (M_{max})**. Building codes usually consider other scenarios for the design of structures, using the ground motion with a statistical probability of being exceeded in a given length of time, with different earthquake scenarios considered depending on the application, such as the planned use, lifetime, or importance of a facility. Traditionally, the more critical the structure, the longer the time period used between earthquakes and the larger the design earthquake that has been used. Seismic design parameters in the most recent version of the California Building Code (2013 edition) are based on the **risk-targeted maximum considered earthquake**, with a ground motion that has a 2 percent probability of being exceeded in 50 years and a recurrence interval of about 2,500 years, with an adjustment for risk. Risk is defined as the probability that damage will occur to the proposed structure. Buildings are designed to withstand a 1-percent probability of collapsing in 50 years.. **Seismic design parameters** define what kinds of earthquake effects a structure must be able to withstand. These include peak ground acceleration, duration of strong shaking, the periods of incoming strong motion waves, and the orientation of maximum response of the earthquake's motion.

Geologists, seismologists, engineers, emergency response personnel and urban planners typically have used maximum magnitude and maximum considered earthquakes to evaluate the seismic hazard of a site or area. The assumption is that if we plan for the worst-case scenario, we establish safety margins. As a result, smaller earthquakes, which are more likely to occur, can be dealt with effectively.

As is true for most earthquake-prone regions, many potential earthquake sources pose a threat to Newport Beach. Thus it is also important to consider the overall likelihood of damage from a plausible suite of earthquakes. This approach is called **probabilistic seismic hazard analysis (PSHA)**, and typically considers the likelihood of exceeding a certain level of damaging ground motion that could be produced by any or all faults within a given distance from the site, or city (typically, these analyses consider all seismic sources within 100 km, or 62-miles from the project site).

Regardless of which fault causes a damaging earthquake, there will always be **aftershocks**. By definition, these are smaller earthquakes that happen close to the **mainshock** (the biggest earthquake of the sequence) in time and space. These smaller earthquakes occur as the Earth adjusts to the regional stress changes created by the mainshock. The bigger the mainshock, the greater the number of aftershocks, the larger the aftershocks will be, and the wider the area in which they might occur. On average, the largest aftershock will be 1.2 magnitude units less than the mainshock. This is an average, and there are many cases where the biggest aftershock is larger than the average predicts. The key point is this: any major earthquake will produce aftershocks large enough to cause additional damage, especially to already weakened structures. Consequently, post-disaster response planning must take damaging aftershocks into account.

In California, many agencies are focused on seismic safety issues: the California Geological Survey (CGS), the State's Seismic Safety Commission (SSC), the United States Geological Survey (USGS), the Governor's Office of Emergency Services (Cal OES), the Applied Technology Council (ATC), the California Institute of Technology (Cal Tech), as well as a number of other universities and private foundations. These organizations, in partnership with other State and Federal agencies, have undertaken a rigorous program in California to identify seismic hazards and risks, including active fault identification, ground shaking, ground motion amplification, liquefaction, earthquake induced landslides, and for coastal areas, tsunami inundation zones. Seismic hazard maps have been published and are available for many communities in California through the California Geological Survey. Some of the most significant earthquake-induced hazards with the potential to impact the city of Newport Beach are described below.

Seismic Shaking

Seismic shaking is the seismic hazard that has the greatest potential to severely impact Newport Beach given the City's proximity to several active seismic sources (faults). To give the City a better understanding of the hazard posed by these faults, we performed a deterministic seismic hazard analysis to estimate the Peak Horizontal Ground Accelerations (PHGA) that can be expected at Newport Beach's new City Hall, and at the old City Hall location on Lido Island due to earthquakes occurring on any of the known active or potentially active faults within about 100 km (62 miles) of the City. We also ran the California Geological Survey's interactive probabilistic ground motion analysis to obtain a generalized value of the peak ground motion that could be expected at both of these locations. The difference between these two approaches is that, whereas a deterministic hazard assessment addresses individual sources or scenario events, probabilistic assessments combine all seismic sources and consider the likelihood (or probability) of each source to generate an earthquake. In a probabilistic analysis, a mathematical equation is used to estimate the combined risk posed by all known faults within 62 miles (100 km), and for each fault, a suite of possible damaging earthquakes is considered, each weighed according to its likelihood of occurring in any particular year.

The fault database (including fault locations and earthquake magnitudes of the maximum magnitude earthquakes for each fault) used to conduct these seismic shaking analyses is that used by the California Geological Survey (CGS) and the U.S. Geological Survey (USGS) (Peterson and others, 1996; Cao and others, 2003). Peak ground acceleration (ground shaking) depends on the size of the earthquake, the proximity of the rupturing fault, and local soil conditions. Effects of soil conditions are estimated by use of an attenuation relationship. To develop these relationships, scientists analyze recordings of earthquake shaking on similar soils during earthquakes of various sizes and distances. The peak ground acceleration estimates obtained from these analyses can be then used to provide a general indication of relative earthquake risk at a given site. For individual projects

however, site-specific analyses that consider the precise distance from a given site to the various faults in the region, as well as the local near-surface soil types, should be conducted.

The underlying geologic units do make a difference in the ground motions expected in the city. Lido Island, the location of the old Newport Beach City Hall is underlain by soft, unconsolidated estuarine deposits, which can greatly amplify earthquake shaking. The new City Hall location is underlain by older marine sediments that have more shear strength than the estuarine sediments. To quantify the degree of amplification, velocity measurements of earthquake shear-waves and other site-specific sub-surface analyses would be needed. A generalized estimate, however, can be obtained by using any of several attenuation relations that have been developed for soft soils in the western United States. For the purposes of this report, we used deterministic analysis software by Blake (2000), and the attenuation relationships of Boore and others (1997) for a soil with a near-surface shear-wave velocity of 520 meters per second (m/s) for the new City Hall location, and 250 m/s for the old City Hall location. The deterministic analysis yielded a mean peak horizontal ground acceleration (PHGA) value of 0.46g for the new location, and 0.65g for the previous City Hall location. These values show that the new City Hall location is anticipated to experience significantly lower seismic shaking than the older location, although both ground acceleration values are in the moderate to high range (see Table 6-1 and Map 6-2B). The level of shaking calculated for the Lido Island location can be applied to other similar areas in the City, such as Balboa Island and the Newport Bay area, with even higher shaking levels anticipated as a result of an earthquake on the section of the Newport-Inglewood fault that extends through the western portion of the City. Shaking at these levels can cause damage even to newer buildings that are constructed in accordance with more stringent building standards; older structures can be damaged extensively.

Using the level of shaking required for the design of new structures in the most recent building code, the risk-targeted peak ground acceleration for the new City Hall location is 0.615g. This probabilistic ground motion value is in the moderate to high range for southern California (see Maps 6-2A and 6-2B), and reflects the fact that the City is located near several major fault systems with moderate to high earthquake recurrence rates. These levels of shaking can be expected to cause damage, particularly to older and poorly constructed buildings.

Table 6-3 shows:

- The closest approximate distance, in kilometers and miles, between Newport Beach's City Hall (new and prior locations) and each of the main faults considered in the analysis;
- the maximum magnitude earthquake (M_{max}) each fault is estimated capable of generating;
- the intensity of ground motion, expressed as a fraction of the acceleration of gravity (g), that could be experienced in the Newport Beach area if the M_{max} occurs on one of these faults (values given range from the median to median plus 1 sigma standard deviation); and
- the Modified Mercalli seismic Intensity (MMI) values estimated to be felt in the City as a result of the M_{max} on each one of these faults.

In general, peak ground accelerations and seismic intensity values decrease with increasing distance away from the causative fault. However, local site conditions, such as soft soils or the top of ridges, can amplify the seismic waves generated by an earthquake, resulting in localized higher accelerations than those listed here. The strong ground motion values presented here should therefore be considered as average values; higher values may occur locally in response to site-specific conditions.

Those faults that can cause peak horizontal ground accelerations of about 0.1g or greater (Modified Mercalli Intensities greater than VII) in the Newport Beach area are listed in Table 6-3. For a map

showing most of these faults, refer to Map 6-1. Those faults included in Table 6-3 that would have the greatest impact on the Newport Beach area, or that are thought to have a higher probability of causing an earthquake, are described in more detail in the following pages.

Table 6-3: Estimated Horizontal Peak Ground Accelerations and Seismic Intensities in the Newport Beach Area (Deterministic Analysis)

Fault Name	Distance to City Hall (km) New, Prior	Distance to City Hall (mi) New, Prior	Magnitude of M_{max} *	PGA (g) from M_{max}	MMI from M_{max}
Newport-Inglewood (LA Basin)	4.8, 0.4	3.0, 0.3	7.1	0.40-1.1	X-XI
San Joaquin Hills Thrust	0 – 5.4	0 – 3.4	6.6	0.46-1.0	X-XI
Newport-Inglewood (Offshore)	5.0, 3.1	3.1, 1.9	7.1	0.42-0.98	X-XI
Compton Thrust	19.4, 14.3	12.1, 9.0	6.8	0.19-0.62	VIII-X
Palos Verdes	23.4, 19.3	14.5, 12.0	7.3	0.18-0.45	VIII-X
Puente Hills Blind Thrust	35.4, 34.7	22.0, 21.6	7.1	0.15-0.32	VIII-IX
Coronado Bank	38.2, 38.7	23.7, 24.0	7.6	0.15-0.32	VIII-IX
Chino-Central Ave. (Elsinore)	30.3, 33.6	18.8, 20.9	6.7	0.10-0.26	VII-IX
Whittier (Elsinore)	33.6, 34.5	20.9, 21.4	6.8	0.10-0.22	VII-VIII
Sierra Madre	58.4, 58.3	36.3, 36.2	7.2	0.06-0.22	VII-IX
San Andreas – Whole Southern	82.6, 84.6	51.3, 52.6	8.0	0.08-0.21	VII-VIII
Anacapa-Dume	86.8, 81.9	53.9, 50.9	7.5	0.04-0.22	VI-VIII
Elsinore-Glen Ivy	34.9, 37.8	21.7, 23.5	6.8	0.10-0.21	VII-VIII
San Andreas – 1857 Rupture	82.6, 84.8	51.3, 52.7	7.8	0.07-0.19	VI-VIII
Rose Canyon	68.2, 72.2	42.4, 44.2	7.2	0.05-0.16	VI-VII
Santa Monica	71.3, 67.1	44.3, 41.7	6.6	0.03-0.15	V-VIII
Malibu Coast	77.0, 72.4	47.8, 45.0	6.7	0.03-0.15	V-VIII
Hollywood	65.7, 62.5	40.8, 38.8	6.4	0.03-0.14	V-VIII

Abbreviations used in Table 6-3:

mi – miles; **km** – kilometer; **M_{max}** – maximum magnitude earthquake; **PGA** – peak ground acceleration as a percentage of g, the acceleration of gravity; **MMI** – Modified Mercalli Intensity.

* The M_{max} reported herein are based on the fault parameters published by the CGS (Cao et al., 2003; CDMG, 1996). However, as described further below in the text, recent paleoseismic studies suggest that some of these faults, like the Whittier and Sierra Madre faults, can generate even larger earthquakes than those listed above. In general, areas closer to a given fault will generally experience higher accelerations than areas farther away, therefore, as an example, the northern portion of the city, closer to the Whittier fault, would experience higher accelerations than those reported herein.

Notes: For each of the two locations summarized in Table 6-3, we ran a total of six deterministic analyses using three different attenuation relations, where each attenuation relation was in turn run for the median value, and for an uncertainty equal to the median plus one sigma standard deviation. The attenuation relations used include Boore et al.’s (1997) horizontal PGA relation, Bozorgnia, Campbell and Niazi’s (1999) horizontal PGA relation, and Campbell and Bozorgnia (1997 revised) relation. The peak ground accelerations provided encompass the range in ground motions calculated in these runs.

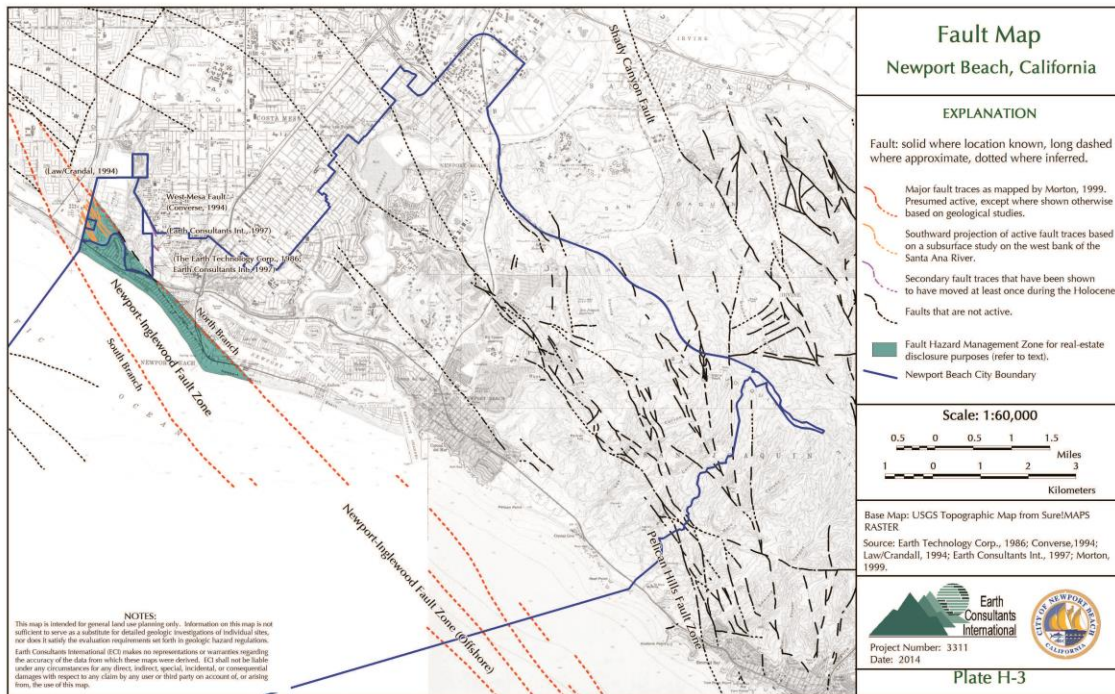
There are several additional faults that could generate low to moderate shaking at the City that are not included in the table above. These include the Raymond, Verdugo, Clamshell-Sawpit, the various segments of the San Jacinto fault, other segments of the San Andreas and Elsinore faults, and the San Gabriel fault.

Newport-Inglewood Fault Zone

The northwest-trending Newport-Inglewood fault zone (NIFZ) is 145 miles long and extends onshore from Santa Monica south to Newport Beach. At Newport Beach, the fault continues offshore and lines up with a deep submarine canyon (Fischer and Mills, 1991) known as the Newport Submarine Canyon. The offshore segment of the fault joins the Rose Canyon fault, which extends southeasterly through San Diego to the international border. The Newport-Inglewood fault zone is discontinuous, consisting of a series of left-stepping en echelon fault strands, each up to 4 miles long. Onshore, the fault zone is marked by a series of uplifts and anticlines including Newport Mesa, Huntington Mesa, Bolsa Chica Mesa, Alamitos Heights and Landing Hill, Signal Hill and Reservoir Hill, Dominguez Hills, Rosecrans Hills, and Baldwin Hills (Barrows, 1974). These anticlines are traps for oil and have been drilled successfully since the beginning of the last century.

The NIFZ extends across the westernmost portion of Newport Beach (see Maps 6-1 and 6-4). In this area, the fault zone is over 1.5 miles wide and consists of many discontinuous primary fault strands and several short secondary fault traces. Several studies in the Newport Beach area and adjacent regions have identified multiple strands of the NIFZ that have displaced Holocene-age terraces and sediments (Converse Consultants, 1994; Shlemon et al., 1995; Grant et al., 1997; Earth Consultants International, 1997).

Map 6-4: Faults Mapped in the Newport Beach Area
 (for a larger scale of this map, refer to Plate H-3 in Appendix H)



The slip rate for the NIFZ is poorly constrained at between 0.3 to 3.5 mm/yr. A study by Woodward-Clyde Consultants in 1979 calculated a slip rate of 0.5 mm/yr for the southern onshore segment of the NIFZ. This is consistent with long-term slip rates of 0.31 – 0.52 mm/yr calculated by Freeman et al. (1992) by correlating sediment layers on one side of the fault to a best match on the opposite side of the fault. Paleoseismic studies by Grant et al. (1997) also suggest a slip rate of between 0.34 to 0.55 mm/yr for the onshore segment. Fischer and Mills (1991) estimated a slightly higher slip rate of between 1.3 and 3.5 mm/yr for the offshore segment of the NIFZ between San

Mateo Point and Newport Beach with an earthquake recurrence interval of between 200 and 800 years. Lindvall and Rockwell (1995) calculated a maximum slip rate of 2 mm/yr for the Rose Canyon fault, the southern continuation of the NIFZ.

Paleoseismic studies by Grant et al. (1997) and Shlemon et al. (1995) have shown that the onshore segment of the NIFZ has had three to five ground rupturing earthquakes in the past 11,700 (+/-700 years). This is consistent with the recurrence interval calculated by Fischer and Mills (1991) for the offshore segment of the NIFZ. The last significant earthquake on the NIFZ was the magnitude 6.3 Long Beach earthquake. This earthquake did not break the ground surface. A maximum earthquake of magnitude 7.1 on the onshore segment of the NIFZ has the potential to generate strong ground motions in the Newport Beach area, with peak horizontal ground accelerations of between 0.4g and 1.1g (see Table 6-3). Similarly, a 7.1 earthquake on the offshore segment of the NIFZ could generate peak horizontal ground acceleration in the Newport Beach area of between 0.42g and 0.98g.

San Joaquin Hills Fault

Uplifted marine terraces between Huntington Beach and San Juan Capistrano suggest the presence of a southwest-dipping blind thrust beneath the San Joaquin Hills (see Map 6-1), adjacent to the Newport-Inglewood fault zone (Grant et al., 1999). Based on structural modeling of dated marine terraces, Grant et al. (1999) calculated a slip rate of about 0.42-0.79 mm/yr and a minimum average recurrence interval of about 1,600 to 3,100 years for moderate size earthquakes on this fault. Uplift of late Holocene shorelines and marsh deposits above the active shoreline are attributed to a relatively recent earthquake larger than magnitude 7 on the San Joaquin Hills fault (Grant et al., 2002). Radiocarbon dating and pollen analyses suggest this earthquake occurred between A.D. 1635 and A.D. 1855. Rivero et al. (2000) and Rivero and Shaw (2011) consider this fault to be part of a larger structure that extends offshore to the south. New studies being conducted on this fault zone as of the writing of this report are likely to provide additional information about the activity and seismic hazard posed by these structures.

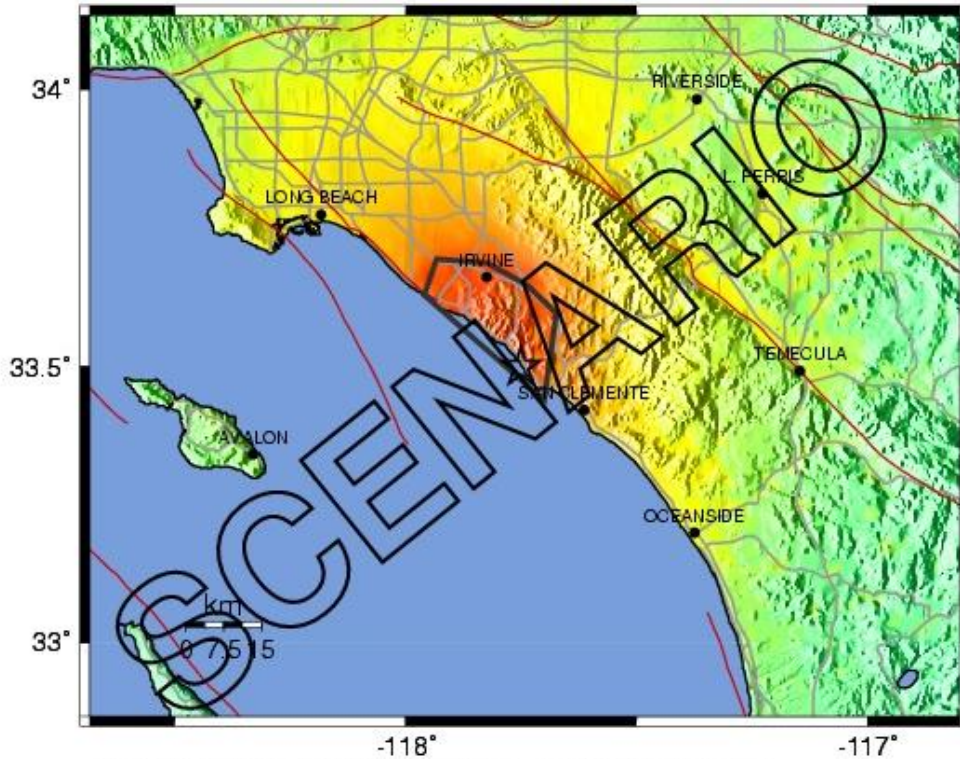
The deterministic analysis conducted for this study indicates that a magnitude 6.6 earthquake on the San Joaquin Hills thrust fault could generate peak horizontal ground accelerations in Newport Beach of between about 0.46g and 1.0g. Modified Mercalli intensities of about X-XI could be expected in the City, as illustrated in Map 6-5, below, and on Table 6-3. A larger, magnitude 7 earthquake on this fault would generate even stronger ground shaking in Newport Beach.

Compton Thrust Fault

The Compton Thrust fault is a blind structure in the southwestern portion of the Los Angeles basin. The fault is part of the Compton-Los Alamitos fault system, postulated to extend over 50 miles from western Santa Monica Bay southeast into northwestern Orange County. Little is known about this fault because it does not break the surface. However, Shaw and Suppe (1996) calculated a slip rate of 1.4 +/- 0.4 mm/yr based on modeling of deep seismic data. In 1997, Mueller reported that geologic structures and units overlying the fault are not deformed, including a 1,900 year-old peat deposit and a 15,000 to 20,000 year-old aquifer, suggesting that the fault is not active. As a result of Mueller's (1997) work, the Compton fault was taken off the CGS active fault database. More recent work, however, suggests that the Compton fault has generated several large-magnitude earthquakes in the Holocene, with a minimum slip rate of about 1.5 mm/yr (Leon et al., 2007; 2009). Oil-well records and seismic lines reviewed by Yeats and Verdugo (2010) show that the Compton-Los Alamitos fault is associated at depth with the Newport-Inglewood fault. In fact, survey records indicate that uplift occurred along the Compton-Los Alamitos trend during the 1933 Long Beach earthquake (Barrows, 1974), indicating that this structure accommodated some of the strain released during that earthquake.

Although associated with the Newport-Inglewood fault, the Compton-Los Alamitos fault is thought capable of generating a thrust-type earthquake on its own. For the purposes of this study, we assumed that the Compton fault has the potential to generate at a minimum a magnitude 6.8 earthquake that would cause peak horizontal ground accelerations of between 0.19g and 0.62g in the City of Newport Beach. Larger magnitude earthquakes ($M > 7$) would generate higher peak accelerations.

Map 6-5: Intensity Map for a Magnitude 6.6 Earthquake Scenario on the San Joaquin Hills Fault



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PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC (%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL (cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Source: http://earthquake.usgs.gov/eqcenter/shakemap/sc/shake/San_Joaquin_Hills_se/

Palos Verdes Fault Zone

The 80- to 115 km-long Palos Verdes fault zone is located primarily offshore and extends in a southeasterly direction from Santa Monica Harbor to the southern San Pedro Channel (Map 6-1). The short onshore segment of the fault extends for 9 miles (15 km) from Redondo Beach to San Pedro and follows the northeastern flank of the Palos Verdes Hills. Offshore, to the southeast, the fault trends across Los Angeles Harbor, and onto the continental shelf where it splays into two discontinuous sub-parallel strands and continues southeast as the Coronado Bank fault zone. Northwest of Redondo Beach, the fault is thought to end in a horsetail splay in Santa Monica Bay,

although some scientists suggest the fault continues northwesterly and joins the Dume fault (Stephenson et al., 1995). The fault is located about 12 miles west-southwest of Newport Beach at its nearest point.

Davis and others (1989) and Shaw and Suppe (1994) modeled the Palos Verdes fault as a southwest-dipping back thrust above a blind thrust. Calculated vertical rates of deformation for the fault based on uplifted marine terraces range from 0.2 to 0.7 mm/yr (Clarke et al., 1985) to 3 mm/yr (Ward and Valensise, 1994). Recent geomorphic studies, however, indicate the fault has a significant right-lateral component. McNeilan et al. (1996) used an offset channel in the Los Angeles Harbor to derive a right-lateral slip rate of 3 mm/yr.

Based on its length and uplift rate, the Palos Verdes fault could produce an earthquake of magnitude 7.3. Given its location relative to the City of Newport Beach, an earthquake of that size could generate ground shaking in the city of about 0.18g to 0.45g, with Modified Mercalli intensities of VIII to X.

Coronado Bank Fault

The 55-mile- (90-km-) long offshore Coronado Bank fault zone is the principal southern continuation of the Palos Verdes fault, extending from the southeast flank of the Lausen Knoll in the southern San Pedro Channel (about 12 miles at its closest approach from Newport Beach) to the La Jolla submarine channel. Bathymetric data show that the fault is well defined by alternating pop-up structures and broad transtensional sags (Legg, 1985; Legg and Kennedy; 1991; Legg and Goldfinger, 2001). Right-lateral motion has been inferred from uplift at left bends in the fault trace and sags at right bends. Little is known about the slip rate or return time of large events on the fault, although a roughly estimated slip rate of 2-3 mm/yr for the Coronado Bank fault zone is based on rates derived on the offshore segment of the Palos Verdes fault. If the Coronado Bank fault zone ruptures producing a maximum magnitude 7.6 earthquake, it could generate peak ground accelerations in Newport Beach of between about 0.15g and 0.32g.

Puente Hills Thrust Fault

In 1999, Shaw and others announced the discovery of a blind thrust fault that extends from northern Orange County to the Los Angeles metropolitan area. The fault does not extend upward to the surface, which is why it is called blind, although it is expressed at the surface by a series of low hills, including the Puente Hills on its eastern end. These hills have risen over the surrounding landscape in response to movement on the underlying fault; Dolan and others (2003) believe that the hills rise 1 to 2 meters (3 to 6 feet) every time the Puente Hills thrust fault breaks in a large magnitude earthquake of M_w 7.2 to 7.5.

Dolan and others' (2003) studies suggest that the fault has experienced four large earthquakes in the past about 11,000 years. Smaller earthquakes that rupture only a section of the fault are also possible, as evidenced by the Whittier Narrows earthquake of 1987, which is now attributed to rupture of a small, deep patch of the Santa Fe Springs segment of the Puente Hills thrust. Thrust faults typically generate stronger ground shaking than strike-slip faults, as the ground above the plane of the fault is moved up and over the underlying plane. Ground shaking from earthquakes on these types of faults is also felt over a broader area, tends to last longer, and has more of the lower frequency seismic waves. All of these characteristics are especially damaging to high-rise buildings and large structures, like freeway overpasses. In fact, a 2005 study on the impact that an earthquake on the Puente Hills fault would have on Los Angeles estimates between 3,000 and 18,000 fatalities, and more than \$250 billion in total losses (Field et al., 2005), making this fault "The Big One" for the Los Angeles area. A magnitude 7.1 earthquake on the Puente Hills thrust fault is estimated to generate ground accelerations in the Newport Beach area of between 0.15g and 0.32g; stronger

shaking could be experienced if the fault breaks in a larger magnitude earthquake, as indicated above. According to Dolan et al. (2003), this fault last ruptured several thousand years ago, although when exactly is unknown. Therefore, there is the possibility that this fault could rupture again in the not-too-distant future.

Elsinore – Chino - Whittier Fault Zone

The 125-mile (200-km) long Elsinore fault is part of the San Andreas fault system in southern California and accommodates about ten percent of the motion between the Pacific and North American plates (WGCEP, 1995). The fault extends northwesterly from the US-Mexico border to north of the Santa Ana Mountains and is divided, from south to north, into the Coyote Mountain, Julian, Temecula, and Glen Ivy segments. North of the Santa Ana Mountains the fault splits into the Whittier and Chino faults. The fault has historically produced a ~M 6 earthquake on the Glen Ivy segment (Toppozada and Parke, 1982; Rockwell et al., 1986), and a M>6.9 event on the Laguna Salada fault, the southern extension of the Elsinore fault in Mexico (Rockwell, 1989; Mueller and Rockwell, 1995). The Pescadores and Borrego faults, which are considered southern extensions of the Laguna Salada fault, ruptured in 2010, causing the Easter Sunday earthquakes in northern Mexico that were felt over a broad area of southern California. All of these events indicate that the Elsinore fault system is active and capable of producing destructive earthquakes. The 2007 Working Group on California Earthquake Probabilities (WGCEP, 2008) assigned the Elsinore fault an 11 percent probability of rupturing in a M>6.7 earthquake in the next 30 years.

Studies of the Wildomar strand of the Temecula segment yielded minimum late Holocene slip rates of about 4.2 mm/yr (Bergmann et al., 1993). This is roughly consistent with slip rates of about 5 mm/yr derived from dated offset alluvial fan deposits on the Glen Ivy segment to the north (Millman and Rockwell, 1986), and the Julian segment to the south (Vaughan and Rockwell, 1986). Although no individual earthquakes have been directly dated on the Wildomar fault, paleoseismic studies on the Murrieta Creek fault, an oblique-slip fault secondary to the Temecula segment, suggest an average recurrence interval of 300 to 700 years for the Elsinore fault in the Murrieta area. Paleoseismic studies on the southeastern end of the Temecula segment, near Agua Tibia Mountain, however, suggest a longer average recurrence interval of 550 to 600 years for the segment (Vaughan et al., 1999).

The Chino fault bounds the eastern flank of the Chino Hills and extends from the Los Serranos area of Chino Hills southwestward to Corona, for a distance of approximately 13 miles (21 km). For decades, the Chino fault was considered primarily a reverse, potentially active fault, but recent studies have shown that it is primarily a right-lateral strike-slip fault (with a minor reverse component), and that it has moved at least once in the Holocene (the past about 11,000 years) (Treiman, 2002a; Walls and Gath, 2001). Given these findings, the fault was upgraded to active, and zoned under the guidelines of the Alquist-Priolo Earthquake Fault Zone Act (Treiman, 2002a). The Central Avenue fault is to the east of the Chino fault, buried under sediments of the Chino Basin. This fault forms a barrier to ground water but at this time is not thought to be an active structure (Treiman, 2002a).

The rate of slip on the Chino fault is still being resolved. Fault experts believe that the Elsinore fault, which has a slip rate of 5 to 6 mm/yr, is transferring that strain northward onto the Whittier and Chino faults. As discussed further below, studies of the Whittier fault suggest that it has a slip rate of 2 to 3 mm/yr, suggesting that the Chino fault could be carrying a similar amount of strain. However, a paleoseismic study of the Chino fault conducted by Walls and Gath (2001) yielded a late Quaternary slip rate for this fault of only 0.36 to 0.51 mm/yr. If the Chino fault is indeed now slipping at a rate of less than 1 mm/yr, then some of the strain from the Elsinore fault may be responsible for aseismic (not earthquake-induced) folding and uplifting of the Chino (Puente) Hills,

and other structures, such as the East Coyote anticline (Bjorklund and Burke, 2002; Myers et al., 2003; Madden and Yeats, 2008). Future studies of the Chino fault are expected to better define its slip rate and potential seismic hazard to the region.

Even with a relatively low rate of slip, the Whittier fault zone is considered one of the most prominent structural features of the Los Angeles basin. The fault zone extends from the Santa River northwestward to the Whittier Narrows area, a distance of approximately 24 miles (38 km). Southeast of the Santa Ana River, the Whittier fault merges with the Elsinore fault. Much of the movement of the Whittier fault is late Pleistocene and younger, as indicated by tilted, locally overturned and faulted bedrock less than 2 million years old, and faulted alluvium.

No major historical earthquakes have been attributed to the Whittier fault. However, trenching studies have documented recurrent movement of this fault in the past 17,000 years (Gath et al., 1992; Patterson and Rockwell, 1993). Based on radiocarbon dating of faulted and unfaulted alluvium exposed in trenches, the two most recent surface rupturing earthquakes on this fault occurred between 1,400 and 2,200 years ago, and 3,000 and 3,100 years ago, respectively (Patterson and Rockwell, 1993). These values give a minimum recurrence interval of 760 (+640, -274) years (WGCEP, 1995). Since a minimum of at least 1,400 years has passed since the last surface-rupturing event occurred on the Whittier fault, the fault is thought to be at or near the end of its cycle and is therefore likely to generate an earthquake in the not too distant future. Based on these trenching studies, the Whittier fault is thought to be moving at a rate of about 2.5 +/- 1 mm/yr.

The deterministic analysis for Newport Beach estimates peak ground accelerations of about 0.10g to 0.26g for a magnitude 6.7 earthquake on the Chino segment, 0.10g to 0.22g for a magnitude 6.8 earthquake on the Whittier segment, and about 0.10g to 0.21g based on a magnitude 6.8 earthquake on the Glen Ivy segment of the Elsinore fault. Some geologists believe that the Whittier fault is capable of generating a 7.1 magnitude earthquake. Such an earthquake would result in stronger ground shaking in the Newport Beach area than the values reported herein (see the Modified Mercalli intensities estimated from a magnitude 6.8 earthquake scenario on the Whittier fault shown on Map 6-6 below).

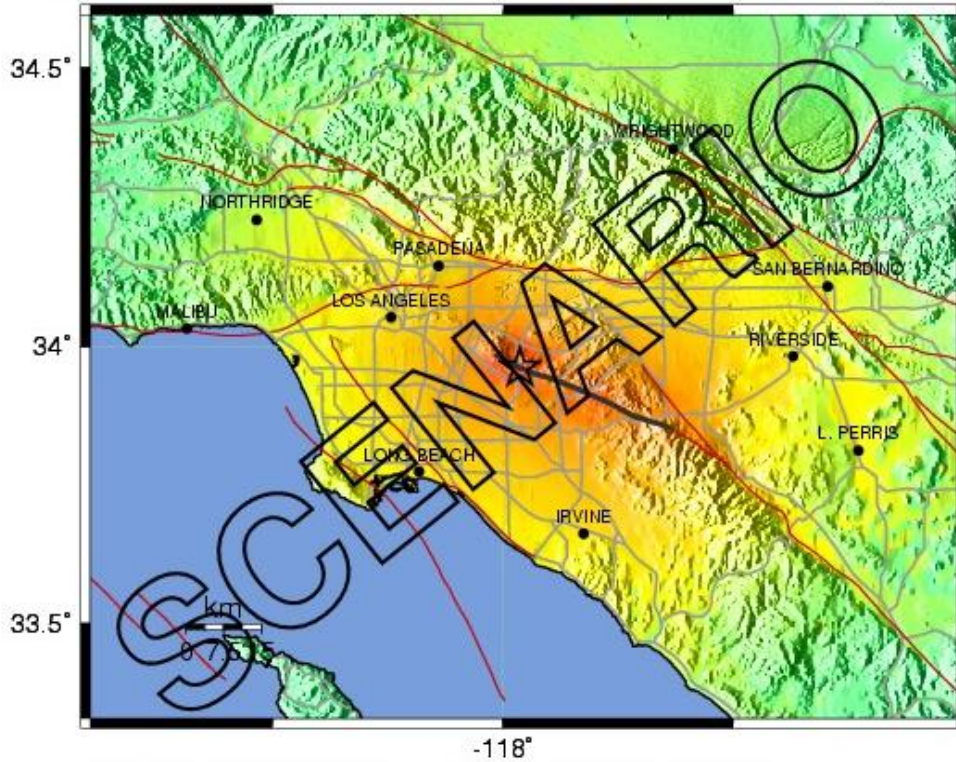
Sierra Madre Fault Zone

The Sierra Madre fault zone is a north-dipping reverse fault zone approximately 47 miles (75 km) long that extends along the southern flank of the San Gabriel Mountains from San Fernando to San Antonio Canyon, where it continues southeastward as the Cucamonga fault. The Sierra Madre fault has been divided into five segments, each with a different rate of activity.

The northwestern-most segment of the Sierra Madre fault (the San Fernando segment) ruptured in 1971, causing the M_w 6.7 San Fernando (or Sylmar) earthquake. As a result of this earthquake, the Sierra Madre fault has been known to be active. In the 1980s, Crook and others (1987) studied the Transverse Ranges using general geologic and geomorphic mapping, coupled with a few trenching locations. Based on this work, they suggested that segments of the Sierra Madre fault east of the San Fernando segment have not generated major earthquakes in several thousands of years, and possibly as long as 11,000 years. By California's definitions of active faulting, most of the Sierra Madre fault would therefore be classified as not active. Then, in the mid-1990s, Rubin et al. (1998) trenched a section of the Sierra Madre fault in Altadena and determined that this segment had ruptured at least twice in the last 15,000 years, causing magnitude 7.2 to 7.6 earthquakes. This suggests that the Los Angeles area is susceptible to infrequent, but large earthquakes on the Sierra Madre fault. Rubin et al.'s (1998) trenching data show that during the last earthquake, the ground was displaced along the fault as much as 13 feet (4 meters) at the surface, and that total displacement in the last two events adds up to more than 34 feet (10.5 meters)! Similar results

were reported by Tucker and Dolan (2001) from a trenching study they conducted in San Dimas, at the eastern end of the Sierra Madre fault. Their findings indicate that the eastern section of the fault last ruptured more than 8,000 years ago, and that the fault slipped more than 14 meters (46 feet) between about 24,000 and 8,000 years ago, for a slip rate of between 0.6 and 0.9 mm/yr.

Map 6-6: Intensity Map for a Magnitude 6.8 Earthquake Scenario on the Whittier Fault



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PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC (%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL (cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Source: http://earthquake.usgs.gov/eqcenter/shakemap/sc/shake/Whittier6.8_se/

Although the Sierra Madre fault apparently slips at a slow rate of between 0.5 and 1 mm/yr (Walls et al., 1998; Tucker and Dolan, 2001), over time, it can accumulate a significant amount of strain. The paleoseismic data obtained at the Altadena site were insufficient to estimate the recurrence interval and the age of the last surface-rupturing event on this segment of the fault. At Horsethief Canyon in San Dimas, Tucker and Dolan (2001) calculated a recurrence interval of about 8,000 years using a slip rate of 0.6 mm/yr and a slip per event of 15 feet (5 meters). Therefore, if the last event occurred about 8,000 years ago, it is possible that these segments of the Sierra Madre fault are near the end of their cycle, and are likely to generate an earthquake in the not-too-distant future.

The deterministic analysis for the Newport Beach City Hall area estimates peak ground accelerations of about 0.06g to 0.22g, based on a magnitude 7.2 earthquake on the central segment of the Sierra Madre fault. A larger earthquake on this fault could generate stronger peak ground accelerations.

San Andreas Fault Zone

The San Andreas fault is the principal boundary between the Pacific and North American plates, and as such, it is considered the “Master Fault” because it has frequent (geologically speaking), large earthquakes, and it controls the seismic hazard in southern California. The fault extends over 750 miles (1,200 kilometers), from near Cape Mendocino in northern California to the Salton Sea region in southern California. At its closest approach, the San Andreas fault is approximately 51 miles (82 km) north-northeast of Newport Beach. Many refer to an earthquake on the San Andreas fault as “The Big One,” and for many parts of southern California, this designation is indeed true. Other areas, including Newport Beach, are actually at greater risk from other faults. Nevertheless, the San Andreas fault should be considered in all seismic hazard assessment studies in southern California given its high probability of causing an earthquake in the near future. In 2007-2008, a group of scientists referred to as the 2007 Working Group on California Earthquake Probabilities (WGCEP, 2008) calculated that the southern San Andreas fault had a 59% probability of causing an earthquake of at least magnitude 6.7 in the next 30 years. That probability increases with each passing year without an earthquake.

Large faults, such as the San Andreas fault, are generally divided into segments in order to evaluate their future earthquake potential. The segments are generally defined at discontinuities along the fault that may affect the rupture length. Each segment is assumed to have a characteristic slip rate (rate of movement averaged over time), recurrence interval (time between moderate to large earthquakes), and displacement (amount of offset during an earthquake). While this methodology has some value in predicting earthquakes, historical records and studies of prehistoric earthquakes show that it is possible for more than one segment to rupture during a large quake or for ruptures to overlap into adjacent segments. For example, the last major earthquake on the southern portion of the San Andreas fault (and the largest earthquake reported in California) was the 1857 Fort Tejon (magnitude 8) event. The 1857 earthquake ruptured the Cholame, Carrizo, Big Bend, and Mojave North and Mojave South sections of the fault, resulting in displacements of as much as 27 feet (9 meters) along the rupture zone. The central and southern San Andreas fault is divided into ten sections named, from north to south, Parkfield, Cholame, Carrizo, Big Bend, Mojave North, Mojave South, San Bernardino North, San Bernardino South, San Geronio-Garnet Hill, and Coachella (WGCEP, 2008).

Peak ground accelerations in the Newport Beach area as a result of the 1857 earthquake are estimated to have been between about 0.07 and 0.19g. Rupture of these fault segments as a group, during a single earthquake, is thought to occur with a recurrence interval of between 104 and 296 years. Map 6-7 shows the seismic intensities that would be expected in the southern California areas if a repeat of the 1857 earthquake occurred.

If the entire southern section of the San Andreas ruptured in a magnitude 8 earthquake, peak horizontal ground accelerations in Newport Beach are estimated at between 0.08 and 0.21g. This earthquake would generate Modified Mercalli intensities in the VII to VIII range. Given its distance from the City, the shaking associated with this event would feel like rolling waves, with the duration of shaking lasting minutes, rather than seconds.

**Map 6-7: Intensity Map for a Magnitude 7.8 Earthquake Scenario
on the San Andreas Fault (Repeat of the 1857 Fort Tejon Earthquake)**



Source: http://earthquake.usgs.gov/eqcenter/shakemap/sc/shake/1857_se/

Fault Rupture

Primary fault rupture refers to fissuring and offset of the ground surface along a rupturing fault during an earthquake. Primary ground rupture typically results in a relatively small percentage of the total damage in an earthquake, but straddling a rupturing fault can cause severe damage to structures. Development constraints within active fault zones were implemented in 1972 with passage of the California Alquist-Priolo Earthquake Fault Zoning Act. This law prohibits the construction of new habitable structures astride an active fault and requires special geologic studies to locate, and evaluate whether a fault has ruptured the ground surface in the last about 11,000 years. If an active fault is encountered, structural setbacks from the fault are defined.

The Newport-Inglewood fault is the only known fault with the potential to generate primary surface rupture in the City of Newport Beach. The North Branch of the Newport-Inglewood fault as mapped by Morton (1999) comes on shore (from the south) near the intersection of Balboa

Boulevard and 15th Street, then crosses the Newport Channel and continues through the Coast Highway-Balboa Boulevard intersection (Map 6-4). The fault trace then continues through the foot of the bluffs, across the old Newport-Banning oil field, and into the city of Huntington Beach. The South Branch comes on shore in Huntington Beach, just up the coast from the Santa Ana River (Map 6-4). In Newport Beach, the North Branch is not considered sufficiently active and well defined by the CGS, and as a result, the fault in the Newport Beach area has not been zoned under the guidelines of the Alquist-Priolo Earthquake Fault Zoning Act. Farther north, the fault is better defined, which is why Alquist-Priolo Earthquake Fault Zones have been defined for the North Branch in Huntington Beach.

The lowland area of West Newport that is thought to be underlain by the North Branch of the fault (see Map 6-4) was developed extensively prior to recognition of the Newport-Inglewood fault as a surface rupture hazard. Therefore, there are no studies of the fault zone in the West Newport and Balboa Peninsula areas. Furthermore, the sediments in these areas are too young, and ground water is too close to the ground surface for trenching to be used as a successful fault study method. Subsurface studies using other techniques such as cone penetrometer testing (CPTs, see Grant et al., 1997) or geophysics could be used along the beach, but, to our knowledge, this has not been tried in this area. On the elevated terrace of Newport Mesa, however, several fault studies have been conducted looking for the active strands of the fault. The first studies to identify faults at or near the surface in the Newport Banning area were reportedly conducted jointly by Woodward-Clyde Consultants and the West Newport Oil Company in 1981 and 1985. Additional studies have been conducted by The Earth Technology Corporation (1986) and by Earth Consultants International (1997). The results of the 1981 study were published (Guptil and Heath, 1981) because one of the exposures reviewed – located approximately 600 feet northwest of the intersection of Pacific Coast Highway and Superior Avenue – suggested that the 1933 earthquake had actually ruptured the ground surface. This finding was not confirmed by The Earth Technology Corporation (1986) study who reported that the fault does not offset a well-developed soil profile estimated to be about 100,000 years old (Bryant, 1988).

The 1985 study (summarized by The Earth Technology Corporation, 1986) exposed a broad area of faulting in the western central and southeastern portion of the mesa. The faults in the western portion of the mesa are roughly coincident with the mapped trace of the North Branch of the fault (see Map 6-4). However, the 1985 study did not resolve the length, width or age of the faults. Then in 1986, The Earth Technology Corporation found that the faults encountered were not active under the criteria of the Alquist-Priolo Act. With one exception in the southeastern portion of the mesa discussed further below, this finding was confirmed locally by Earth Consultants International in 1997. These studies combined suggest that the North Branch of the Newport-Inglewood fault, as mapped, is not active, at least not in this area of Newport Beach.

Converse Consultants (1994) found a small fault, the West Mesa fault, near the western terminus of West 16th Street, while conducting a geologic study and grading for a filtration water plant (Map 6-4). The West Mesa fault trends between 5 and 30 degrees west of north, and is interpreted to have moved in the past 11,000 years, making it active. Earth Consultants International (1997) then trenched south of the Converse (1994) exposure in an attempt to find the southern continuation of this fault, but the fault was not found, suggesting that the fault is not laterally extensive. However, Earth Consultants International (1997) did find another small active fault about 600 feet to the south of the Converse study that strikes 50 degrees west of north, roughly parallel to the regional trend of the Newport-Inglewood fault. In the exposure, the fault had 12 to 18 inches of vertical separation, extended upward into the soil, and was therefore interpreted to have ruptured at least once in the past 11,000 years, probably co-seismically with movement on the main Newport-Inglewood fault.

Further, in reviewing previous work in the Newport Mesa area, Earth Consultants International (1997) concluded that a narrow fault zone mapped by The Earth Technology Corporation (1986) was not conclusively shown to be inactive. This fault zone trends 5 to 12 degrees west of north, similar to the orientation of the fault exposed by Converse (1994). All of these faults in the eastern portion of the mesa are not considered seismogenic (earthquake-producing) because of their small separations, narrow width, and non-ideal orientations. The offset seen on these faults probably resulted from co-seismic slip during an earthquake on a strand of the Newport-Inglewood fault farther to the south. Nevertheless, several inches of ground offset could cause severe damage to overlying structures. Consequently, although the hazard from primary surface rupture on these small faults is possibly low, building setbacks from these faults are appropriate. Alternatively, engineering strengthening of the foundations straddling the faults could be considered.

Finally, two paleoseismic investigations, one near Bolsa Chica (Grant et al., 1997) and the other on the west bank of the Santa Ana River (Law/Crandall, Inc., 1994; Shlemon et al., 1995) found evidence for five surface rupturing earthquakes in the past ~11,000 years on the North Branch of the Newport-Inglewood fault. The Law/Crandall (1994) study identified several fault traces south of the mapped trace of the North Branch of the Newport-Inglewood that appear to have moved in the Holocene. In Map 6-4, these fault traces are projected as straight lines from the west bank of the Santa Ana River southward into the Newport Beach area. This shows that the active faults appear to be located south of the North Branch, with active faulting spread over a broad area that most likely spans the area between the North and South branches. However, the location of these faults should be considered approximate at best, until further studies in this area are conducted.

The activity and location of the North Branch, and the faults south of the North Branch farther southeast, along West Newport and the Balboa Peninsula are unknown. Ideally, geologic studies similar in scope to those required by the CGS in Alquist-Priolo Earthquake Fault Zones should be conducted if new development or redevelopment is proposed in these areas. In reality, such investigations are not likely to be successful due to the small lot sizes and very high building density in these portions of the City, combined with the underlying, geologically young beach and sand dune deposits and shallow ground water. Trenching in these areas could also negatively impact adjacent properties. It is herein recommended that a “fault disclosure zone” be placed along the area between the mapped alignments of the North and South branches of the Newport-Inglewood fault, in the area where recent studies suggest that the recently active traces of the fault are located. The purpose of this fault disclosure zone is to make the public aware of the potential hazard (Map 6-4). If detailed geological investigations are conducted, the location and activity status (some of the splays may be proven to have not moved within the last 11,000 years) of the faults shown on Map 6-4 may be refined or modified. The map should be amended as new data become available and are validated.

Although the San Joaquin Hills fault may generate very strong earthquakes, damage from primary surface rupture is low because this fault is “blind.” By definition, a blind thrust is a reverse fault that does not break the surface during an earthquake. For example, the 1994 Northridge earthquake ruptured on the blind Oakridge fault and was the most costly earthquake in U.S. history, but it did not break the surface. However, ground deformation resulting from uplifting of the landmass during a San Joaquin Hills fault quake could damage portions of Newport Beach.

Several other faults, such as the Pelican Hill fault, and the Shady Canyon fault (north of the city) have been mapped in the San Joaquin Hills (see Map 6-4). These faults appear to be confined to the older bedrock units, with no impact on the younger, Holocene terrace and alluvial deposits, and are therefore not considered active. Special geological studies for these faults are not considered warranted at this time.

Liquefaction and Related Ground Failure

Liquefaction is a geologic process that causes various types of ground failure. Liquefaction typically occurs in loose, saturated sediments primarily of sandy composition, in the presence of ground accelerations over 0.2g (Borchardt and Kennedy, 1979; Tinsley and Fumal, 1985). When liquefaction occurs, the sediments involved have a total or substantial loss of shear strength, and behave like a liquid or semi-viscous substance. Liquefaction can cause structural distress or failure due to ground settlement, a loss of bearing capacity in the foundation soils, and the buoyant rise of buried structures. The excess hydrostatic pressure generated by ground shaking can result in the formation of sand boils or mud spouts, and/or seepage of water through ground cracks.

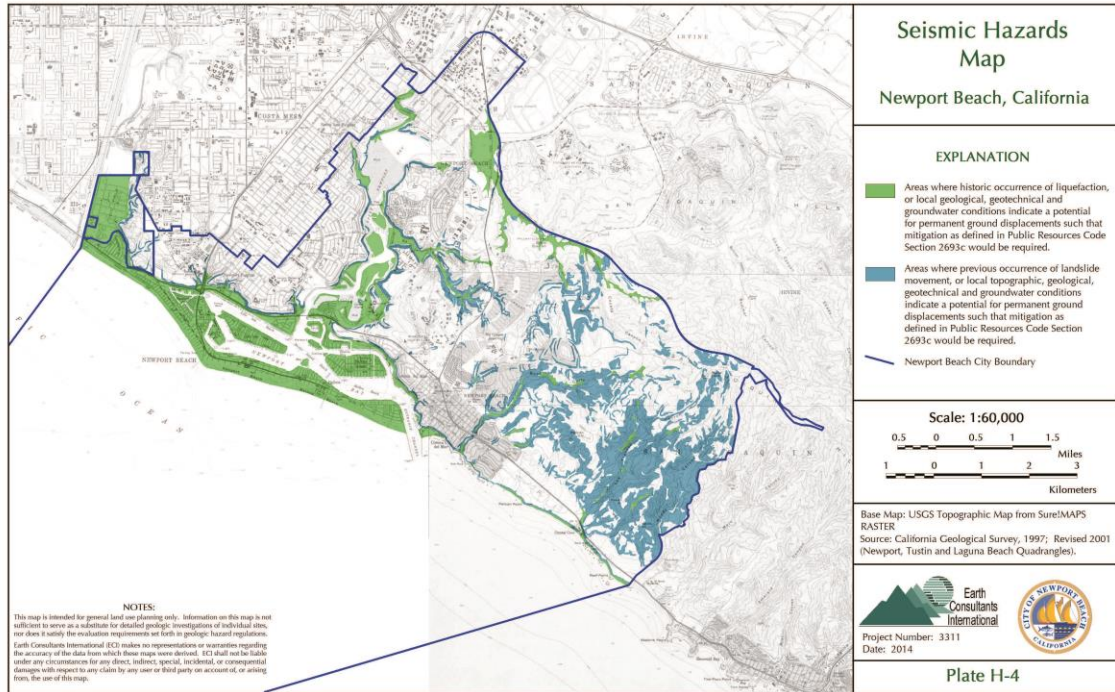
As indicated above, there are three general conditions that need to be met for liquefaction to occur. The first of these – strong ground shaking of relatively long duration – can be expected to occur in the Newport Beach area as a result of an earthquake on any of several active faults in the region. The second condition – loose, unconsolidated sediments consisting primarily of silty sand and sand – occurs along the coastline from West Newport to the tip of Balboa Peninsula, as well as in and around Newport Bay. Young alluvial sediments also occur along the larger drainages (e.g., Bonita Canyon) within the City. The third condition – water-saturated sediments within about 50 feet of the surface – occurs along the coastline, in and around Newport Bay and Upper Newport Bay, in the lower reaches of major streams in Newport Beach, and in the floodplain of the Santa Ana River. Therefore, these are the areas with the potential to experience future liquefaction-induced ground displacements. The potentially liquefiable areas are shown in green on Map 6-8, and are discussed further below.

Structures built on the sand dune deposits lining the coast from the mouth of the Santa Ana River to the end of Balboa Peninsula are highly susceptible to liquefaction during an earthquake because depth to the water table is less than 15 feet. Likewise, buildings on the estuary deposits within and around Newport Bay are equally at risk from seismically induced liquefaction because of the shallow water table (Map 6-8). Areas along major stream channels, such as Bonita and Big Canyon, are also vulnerable to liquefaction, especially during wet climatic conditions/seasons. Liquefaction hazard is also mapped along Buck Gully, Los Trancos Canyon, Muddy Canyon, and the beach area from Corona del Mar to the eastern boundary of Newport Beach near Reef Point (Map 6-8).

Although not mapped, shallow groundwater conditions may occur locally in smaller drainages throughout central and eastern Newport Beach. Since the bedrock that forms the San Joaquin Hills weathers to sand-sized particles, some of the canyons may contain sediments susceptible to liquefaction. For example, sediments lining streams flowing southwest off Pelican Hill may be susceptible to liquefaction. The potential for these areas to liquefy should be evaluated on a case-by-case basis. Additionally, areas of artificial fill that have been placed on liquefiable soils may also be at risk.

It is likely that residential or commercial development will never occur in many of the liquefiable areas, such as Upper Newport Bay, the Newport Coast beaches, and the bottoms of stream channels. However, other structures (such as bridges, roadways, major utility lines, and park improvements) that occupy these areas are vulnerable to damage from liquefaction if mitigation measures have not been included in their design. Construction planned for these areas should include liquefaction mitigation measures, weighing the factors of public safety, the impact to the environment, and the risk of economic loss. For instance, a parking lot at the beach may not warrant ground modification measures, especially if the mitigation measures would be destructive to the environment, but a bridge abutment for a busy roadway would.

Map 6-8: Seismic Hazards in Newport Beach
 (for a larger version of this map, refer to Plate H-4 in Appendix H)



A considerable part of the City’s mapped liquefiable areas (West Newport, Balboa Peninsula, the harbor islands and vicinity) are already built upon, mostly with residential and commercial development. A portion of the City’s active oil field is also built on liquefiable soils. It is likely that a nearby moderate to strong earthquake will cause extensive damage to buildings and infrastructure in these areas. Since retrofitting mitigation measures are generally not feasible, the City should be prepared to respond to damage and disruption in the event of an earthquake.

The types of ground failure typically associated with liquefaction are explained below.

Lateral Spreading

Lateral displacement of surficial blocks of soil as the result of liquefaction in a subsurface layer is called lateral spreading. Even a very thin liquefied layer can act as a hazardous slip plane if it is continuous over a large enough area. Once liquefaction transforms the subsurface layer into a fluid-like mass, gravity plus inertial forces caused by the earthquake may move the mass downslope towards a cut slope or free face (such as a river channel or a canal). Lateral spreading most commonly occurs on gentle slopes that range between 0.3° and 3°, and can displace the ground surface by several meters to tens of meters. Such movement damages pipelines, utilities, bridges, roads, and other structures. During the 1906 San Francisco earthquake, lateral spreads with displacements of only a few feet damaged every major pipeline. Thus, liquefaction compromised San Francisco’s ability to fight the fires that caused about 85 percent of the damage (Tinsley et al., 1985).

Flow Failure

The most catastrophic mode of ground failure caused by liquefaction is flow failure. Flow failure usually occurs on slopes greater than 3 degrees. Flows are principally liquefied soil or blocks of

intact material riding on a liquefied subsurface. Displacements are often in the tens of meters, but in favorable circumstances, soils can be displaced for tens of miles, at velocities of tens of miles per hour. For example, the extensive damage to Seward and Valdez, Alaska, during the 1964 Great Alaskan earthquake was caused by submarine flow failures (Tinsley et al., 1985).

Ground Oscillation

When liquefaction occurs at depth but the slope is too gentle to permit lateral displacement, the soil blocks that are not liquefied may separate from one another and oscillate on the liquefied zone. The resulting ground oscillation may be accompanied by the opening and closing of fissures (cracks) and sand boils, potentially damaging structures and underground utilities (Tinsley et al., 1985).

Loss of Bearing Strength

When a soil liquefies, loss of bearing strength may occur beneath a structure, possibly causing the building to settle and tip. If the structure is buoyant, it may float upward. During the 1964 Niigata, Japan earthquake, buried septic tanks rose as much as 3 feet, and structures in the Kwangishicho apartment complex tilted as much as 60 degrees (Tinsley et al., 1985).

Ground Lurching

Soft, saturated soils have been observed to move in a wave-like manner in response to intense seismic ground shaking, forming ridges or cracks on the ground surface. At present, the potential for ground lurching to occur at a given site can be predicted only generally. Areas underlain by thick accumulation of colluvium and alluvium appear to be the most susceptible to ground lurching. Under strong ground motion conditions, lurching can be expected in loose, cohesionless soils, or in clay-rich soils with high moisture content. In some cases, the deformation remains after the shaking stops (Barrows et al., 1994).

Seismically Induced Slope Failure

Strong ground motions can worsen existing unstable slope conditions, particularly if coupled with saturated ground conditions. Seismically induced landslides can overrun structures, people or property, sever utility lines, and block roads, thereby hindering rescue operations after an earthquake. Over 11,000 landslides were mapped shortly after the Northridge earthquake, all within a 45-mile radius of the epicenter (Harp and Jibson, 1996). Although numerous types of earthquake-induced landslides have been identified, the most widespread type generally consists of shallow failures involving surficial soils and the uppermost weathered bedrock in moderate to steep hillside terrain (these are also called disrupted soil slides). Rock falls and rockslides on very steep slopes are also common. The 1989 Loma Prieta and Northridge earthquakes showed that reactivation of existing deep-seated landslides also occurs (Spittler et al., 1990; Barrows et al., 1995).

A combination of geologic conditions leads to landslide vulnerability. These include high seismic potential; rapid uplift and erosion resulting in steep slopes and deeply incised canyons; highly fractured and folded rock; and rock with inherently weak components, such as silt or clay layers. The orientation of the slope with respect to the direction of the seismic waves (which can affect the shaking intensity) can also control the occurrence of landslides.

Much of the area in eastern Newport Beach has been identified as vulnerable to seismically induced slope failure. Approximately 90 percent of the land from Los Trancos Canyon to the State Park boundary is mapped as susceptible to landsliding by the California Geologic Survey (areas in blue on Map 6-8). The occurrence of numerous Holocene to latest Pleistocene (recent to about 20,000 years old) landslides indicate that slope failures have been common over a relatively short geologic time period and thus, without mitigation, pose a significant hazard to developments in these areas.

Additionally, the sedimentary bedrock that crops out in the San Joaquin Hills is locally highly weathered. In steep areas, strong ground shaking can cause slides or rockfalls in this material. Rupture along the Newport-Inglewood Fault Zone and other faults in southern California could reactivate existing landslides and cause new slope failures throughout the San Joaquin Hills. Slope failures can also be expected to occur along stream banks and coastal bluffs, such as Big Canyon, around San Joaquin Reservoir, Newport and Upper Newport Bays, and Corona del Mar.

Groundwater conditions at the time of the earthquake play an important role in the development of seismically induced slope failures. For instance, the 1906 San Francisco earthquake occurred in April, after a winter of exceptionally heavy rainfall, and produced many large landslides and mudflows, some of which were responsible for several deaths. The 1987 Loma Prieta earthquake however, occurred in October during the third year of a drought, and slope failures were limited primarily to rock falls and reactivation of older landslides that was manifested as ground cracking in the scarp areas but with very little movement (Griggs et al., 1991).

Ridgetop Fissuring and Shattering

Linear, fault-like fissures occurred on ridge crests in a relatively concentrated area of rugged terrain in the Santa Cruz Mountains during the Loma Prieta earthquake. Shattering of the surface soils on the crests of steep, narrow ridgelines occurred locally in the 1971 San Fernando earthquake, but was widespread in the 1994 Northridge earthquake. Ridgetop shattering (which leaves the surface looking as if it was plowed) by the Northridge earthquake was observed as far as 22 miles away from the epicenter. In the Sherman Oaks area, severe damage occurred locally to structures located at the tops of relatively high (greater than 100 feet), narrow (typically less than 300 feet wide) ridges flanked by slopes steeper than about 2.5:1 (horizontal:vertical). It is generally accepted that ridgetop fissuring and shattering is a result of intense amplification or focusing of seismic energy due to local topographic effects (Barrows et al., 1995).

Ridgetop shattering can be expected to occur in the topographically steep portions of the San Joaquin Hills. These areas are rapidly being developed so the hazard associated with ridgetop shattering is increasing. In addition, above ground storage tanks, reservoirs and utility towers are often located on top of ridges, and during strong ground shaking, these can fail or topple over, with the potential to cause widespread damage to development downslope (storage tanks and reservoirs), or disruptions to the lifeline systems (utility towers).

Vulnerability Assessment

The effects of earthquakes span a large area, and large earthquakes occurring in the southern California area would be felt throughout the region. However, the degree to which earthquakes are felt, and the damages associated with them may vary. At risk from earthquake damage are large stocks of old buildings and bridges; many hazardous materials facilities; extensive sewer, water, and natural gas pipelines; earthen dams; petroleum pipelines; and other critical facilities, not to mention private property and businesses. Secondary earthquake hazards, such as liquefaction and earthquake-induced landslides, can be just as devastating as the ground shaking.

Damage to the extensive building stock in the area is expected to vary. Older, pre-1945 steel frame structures may have unreinforced masonry such as bricks, clay tiles and terra cotta tiles as cladding or infilling. Cladding in newer buildings may be glass, infill panels or pre-cast panels that may fail and generate a band of debris around the building exterior (with considerable threat to pedestrians in the streets below). Structural damage may occur if the structural members are subject to plastic deformation that can cause permanent displacements. If some walls fail while others remain intact,

torsion or soft-story problems may result. Overall, modern steel frame buildings have been expected to perform well in earthquakes, but the 1994 Northridge earthquake broke many welds in these buildings, a previously unanticipated problem.

Buildings are often a combination of steel, concrete, reinforced masonry and wood, with different structural systems on different floors or different sections of the building. Combination types that are potentially hazardous include: concrete frame buildings without special reinforcing, precast concrete and precast-composite buildings, steel frame or concrete frame buildings with unreinforced masonry walls, reinforced concrete wall buildings with no special detailing or reinforcement, large capacity buildings with long-span roof structures (such as theaters and auditoriums), large unengineered wood-frame buildings, buildings with inadequately anchored exterior cladding and glazing, and buildings with poorly anchored parapets and appendages (FEMA, 1985). Additional types of potentially hazardous buildings may be recognized after future earthquakes.

Mobile homes are prefabricated housing units that are placed on isolated piers, jackstands, or masonry block foundations (usually without any positive anchorage). Floors and roofs of mobile homes are usually plywood, and outside surfaces are covered with sheet metal. Mobile homes typically do not perform well in earthquakes. Severe damage occurs when they fall off their supports, severing utility lines and piercing the floor with jackstands.

In addition to building types, there are other factors associated with the design and construction of the buildings that also have an impact on the structures' vulnerability to strong ground shaking. Some of these conditions are discussed below:

- **Building Shape** – A building's vertical and/or horizontal shape can be important. Simple, symmetric buildings generally perform better than non-symmetric buildings. During an earthquake, non-symmetric buildings tend to twist as well as shake. Wings on a building tend to act independently during an earthquake, resulting in differential movements and cracking. The geometry of the lateral load-resisting systems also matters. For example, buildings with one or two walls made mostly of glass, while the remaining walls are made of concrete or brick, are at risk. Asymmetry in the placement of bracing systems that provide a building with earthquake resistance, can result in twisting or differential motions.
- **Pounding** – Site-related seismic hazards may include the potential for neighboring buildings to "pound," or for one building to collapse onto a neighbor. Pounding occurs when there is little clearance between adjacent buildings, and the buildings "pound" against each other as they deflect during an earthquake. The effects of pounding can be especially damaging if the floors of the buildings are at different elevations, so that, for example, the floor of one building hits a supporting column of the other. Damage to a supporting column can result in partial or total building collapse.

Damage to the region's critical facilities and infrastructure need to be considered and planned for. Critical facilities are those parts of a community's infrastructure that must remain operational after an earthquake. Critical facilities include schools, hospitals, fire and police stations, emergency operation centers, and communication centers. Plate H-1 shows the locations of the City's fire stations, police stations, schools, and other critical facilities. A vulnerability assessment for these facilities involves comparing the locations of these facilities to the hazardous areas identified in the City, including active and potentially active faults (Map 6-4), liquefaction-susceptible areas (Map 6-8; Plate H-4), unstable slope areas (Map 6-8, and Plates H-4 and H-19), potential dam failure inundation areas (Plate H-9), fire hazard zones (Plate H-13), and sites that generate hazardous materials.

High-risk facilities, if severely damaged, may result in a disaster far beyond the facilities themselves. Examples include power plants, dams and flood control structures, freeway interchanges, bridges, and industrial plants that use or store explosives, toxic materials or petroleum products.

High-occupancy facilities have the potential of resulting in a large number of casualties or crowd-control problems. This category includes high-rise buildings, large assembly facilities, and large multifamily residential complexes.

Dependent-care facilities, such as preschools and schools, rehabilitation centers, prisons, group care homes, and nursing homes, house populations with special evacuation considerations.

Economic facilities, such as banks, archiving and vital record-keeping facilities, airports, and large industrial or commercial centers, are those facilities that should remain operational to avoid severe economic impacts.

It is crucial that critical facilities have no structural weaknesses that can lead to collapse. For example, the Federal Emergency Management Agency (FEMA, 1985) has suggested the following seismic performance goals for **health care facilities**:

- The damage to the facilities should be limited to what might be reasonably expected after a destructive earthquake and should be repairable and not be life-threatening.
- Patients, visitors, and medical, nursing, technical and support staff within and immediately outside the facility should be protected during an earthquake.
- Emergency utility systems in the facility should remain operational after an earthquake.
- Occupants should be able to evacuate the facility safely after an earthquake.
- Rescue and emergency workers should be able to enter the facility immediately after an earthquake and should encounter only minimum interference and danger.
- The facility should be available for its planned disaster response role after an earthquake.

Lifelines are those services that are critical to the health, safety and functioning of the community. They are particularly essential for emergency response and recovery after an earthquake. Furthermore, certain critical facilities designed to remain functional during and immediately after an earthquake may be able to provide only limited services if the lifelines they depend on are disrupted. Lifeline systems include water, sewage, electrical power, communication, transportation (highways, bridges, railroads, and airports), natural gas, and liquid fuel systems. The improved performance of lifelines in the 1994 Northridge earthquake, relative to the 1971 San Fernando earthquake, shows that the seismic codes upgraded and implemented after 1971 have been effective. Nevertheless, the impact of the Northridge quake on lifeline systems was widespread and illustrates the continued need to study earthquake impacts, to upgrade substandard elements in the systems, to provide redundancy in systems, to improve emergency response plans, and to provide adequate planning, budgeting and financing for seismic safety.

Some of the observations and lessons learned from the Northridge earthquake are summarized below (from Savage, 1995; Lund, 1996).

- Several electrical transmission towers were damaged or totally collapsed. Collapse was generally due to foundation distress in towers that were located near ridge tops where

amplification of ground motion may have occurred. One collapse was the result of a seismically induced slope failure at the base of the tower.

- Damage to above ground water tanks typically occurred where piping and joints were rigidly connected to the tank, due to differential movement between the tank and the piping. Older steel tanks not seismically designed under current standards buckled at the bottom (called “elephant’s foot”), in the shell, and on the roof. Modern steel and concrete tanks generally performed well.
- The most vulnerable components of pipeline distribution systems were older threaded joints, cast iron valves, cast iron pipes with rigid joints, and older steel pipes weakened by corrosion. In the case of broken water lines, the loss of fire suppression water forced fire departments to utilize water from swimming pools and tanker trucks.
- Significant damage occurred in water treatment plants due to sloshing in large water basins.
- A number of facilities did not have an emergency power supply or did not have enough power supply capacity to provide their essential services.
- Lifelines within critical structures, such as hospitals and fire stations, may be vulnerable. For instance, rooftop mechanical and electrical equipment is not generally designed for seismic forces. During the Northridge quake, rooftop equipment failed causing malfunctions in other systems.
- A 70-year old crude oil pipeline leaked from a cracked weld, spreading oil for 12 miles down the Santa Clara River.
- A freight train carrying sulfuric acid was derailed causing an 8,000-gallon acid spill and a 2,000-gallon diesel spill from the locomotive.

The above list is by no means a complete summary of the earthquake damage, but it does highlight some of the issues pertinent to the Newport Beach area. All lifeline providers should make an evaluation of the seismic vulnerability within their systems a priority. The evaluation should include a plan to fund and schedule the needed seismic mitigation. The 2014 La Habra earthquake caused several water mains to burst in the epicentral area and vicinity, showing that 20 years after the Northridge earthquake, many of the pipeline distribution systems in the Southern California area have not been upgraded, and are thus vulnerable to seismic shaking.

Risk Analysis

Risk analysis is the third phase of a hazard assessment. Risk analysis involves estimating the damage and costs likely to be experienced in a geographic area over a period of time. Factors included in assessing earthquake risk include population and property distribution in the hazard area, the frequency of earthquake events, landslide susceptibility, buildings, infrastructure, and disaster preparedness of the region. This type of analysis can generate estimates of the damages to the region due to an earthquake event in a specific location. FEMA's software program, HazUS, uses mathematical formulas and information about building stock, local geology and the location and size of potential earthquakes, economic data, and other information to estimate losses from a potential earthquake. A HazUS loss estimation was conducted for the City of Newport Beach as part of the 2008 study using data from the 2000 census with 2006 population numbers and other City-specific modifications to the data as described further below.

Updating the HazUS earthquake loss estimates was not part of the scope of work for the 2014 Plan. However, given that most growth in the City's population is associated with new construction that

is expected to perform well in an earthquake, the losses are anticipated to be similar to those presented here.

HazUS-MH™ is a standardized methodology for earthquake loss estimation based on a geographic information system (GIS). [HazUS-MH™ stands for Hazard US, Multi-Hazard version]. A project of the National Institute of Building Sciences, funded by the Federal Emergency Management Agency (FEMA), it is a powerful advance in mitigation strategies. The HazUS project developed guidelines and procedures to make standardized earthquake loss estimates at a regional scale. With standardization, estimates can be compared from region to region. HazUS is designed for use by state, regional and local governments in planning for earthquake loss mitigation, emergency preparedness, response and recovery. HazUS addresses nearly all aspects of the built environment, and many different types of losses. The methodology has been tested by comparing scenario results with actual losses generated by several past earthquakes. Subject to several limitations noted below, HazUS can produce results that are valid for the intended purposes.

Loss estimation is an invaluable tool, but it must be used with discretion. Loss estimation analyzes casualties, damage and economic loss in great detail. It produces seemingly precise numbers that can be easily misinterpreted. Loss estimation's results, for example, may cite 4,054 left homeless by a scenario earthquake. This is best interpreted by its magnitude. That is, an event that leaves 4,000 people homeless is clearly more manageable than an event causing 40,000 homeless people; and an event that leaves 400,000 homeless would overwhelm a region's resources. However, another loss estimation that predicts 7,000 people homeless should probably be considered equivalent to the 4,054 result. Because HazUS results make use of a great number of parameters and data of varying accuracy and completeness, it is not possible to assign quantitative error bars. Although the numbers should not be taken at face value, they are not rounded or edited because detailed evaluation of individual components of the disaster can help mitigation agencies ensure that they have considered all the important options.

The more community-specific the data that are input to HazUS, the more reliable the loss estimation. HazUS provides defaults for all required information. These are based on best-available scientific, engineering, census and economic knowledge. The loss estimations in this report have been tailored to Newport Beach by using a map of soil types for the City, topographic information provided by the City's GIS department for the flooding component, and updates to the HazUS database contained in the software's October 2006 version. Other modifications made to the data set before running the analyses included:

- updated the database of critical facilities, including the number and location of the fire and police stations in the City, and the number and location of schools in the City [note that since this analysis was conducted, City Hall, the main Fire Department, and the City's Emergency Operations Center have all been moved to a brand new building that is not located in a liquefaction-susceptible area],
- revised the number of beds available in the major hospital in Newport Beach to better represent its current patient capacity, and
- upgraded the construction level for all unreinforced masonry buildings in the City to better represent the City's retrofitting efforts of the last decade.

As useful as HazUS seems to be, the loss estimation methodology has some inherent uncertainties. These arise in part from incomplete scientific knowledge concerning earthquakes and their effect upon buildings and facilities, and in part from the approximations and simplifications necessary for comprehensive analyses.

Users should be aware of the following specific limitations:

- HazUS is driven by statistics, and thus is most accurate when applied to a region, or a class of buildings or facilities. It is least accurate when considering a particular site, building or facility.
- Losses estimated for lifelines may be less than losses estimated for the general building stock.
- Losses from smaller (less than M 6.0) damaging earthquakes may be overestimated.
- Pilot and calibration studies have not yet provided an adequate test concerning the possible extent and effects of landsliding; therefore, the earthquake scenarios do not include losses associated with earthquake-induced slope failure.
- The indirect economic loss module is still relatively new and experimental. While output from pilot studies has generally been credible, this module requires further testing.
- The databases that HazUS draws from to make its estimates are often incomplete or outdated (as discussed above, efforts were made to improve some of the datasets used for the analysis, but for some estimates, the software still relies on the year 2000 census tracts data). This is another reason the loss estimates should not be taken completely at face value.

Essential facilities and lifeline inventory are located by latitude and longitude. However, the HazUS inventory data for lifelines and utilities were developed at a national level and where specific data are lacking, statistical estimations are utilized. Specifics about the site-specific inventory data used in the models are discussed further in the paragraphs below. Other site-specific data used include soil types and liquefaction susceptible zones. The user then defines the earthquake scenario to be modeled, including the magnitude of the earthquake, and the location of the epicenter. Once all these data are input, the software calculates the loss estimates for each scenario.

The loss estimates include physical damage to buildings of different construction and occupancy types, damage to essential facilities and lifelines, number of after-earthquake fires and damage due to fire, and the amount of debris that is expected. The model also estimates the direct economic and social losses, including casualties and fatalities for three different times of the day, the number of people left homeless and number of people that will require shelter, number of hospital beds available, and the economic losses due to damage to the places of businesses, loss of inventory, and (to some degree) loss of jobs. The indirect economic losses component is still experimental; the software developers have checked the estimations against actual past earthquakes, such as the 1989 Loma Prieta, 1994 Northridge, and 2001 Nisqually, Washington earthquakes, but indirect losses are hard to measure, and it typically takes years before these monetary losses can be quantified with any degree of accuracy. Therefore, this component of HazUS is still considered experimental.

HazUS breaks **critical facilities** into two groups: essential facilities and high potential loss (HPL) facilities. Essential facilities provide services to the community and should be functional after an earthquake. Essential facilities include hospitals, medical clinics, schools, fire stations, police stations and emergency operations facilities. The essential facility module in HazUS determines the expected loss of functionality for these facilities. The damage probabilities for essential facilities are determined on a site-specific basis (i.e., at each facility). Economic losses associated with these facilities are computed as part of the analysis of the general building stock. Data required for the analysis include occupancy classes (current building use) and building structural type, or a combination of essential facilities building type, design level and construction quality factor. High potential loss facilities include dams, levees, military installations, nuclear power plants and hazardous material sites.

HazUS divides the **lifeline** inventory into two systems: 1) transportation and 2) utility lifelines. The transportation system includes seven components: highways, railways, light rail, bus, ports, ferry and airports. The utility lifelines include potable water, wastewater, natural gas, crude and refined oil, electric power and communications. If site-specific lifeline utility data are not provided for these analyses, HazUS performs a statistical calculation based on the population served.

General Building Stock Type and Classification: HazUS provides damage data for buildings based on these structural types:

- Concrete
- Mobile home
- Precast concrete
- Reinforced-masonry bearing walls
- Steel
- Unreinforced-masonry bearing walls, and
- Wood frame

and based on these occupancy (usage) classifications:

- Residential (single-family and other residential)
- Commercial
- Industrial
- Agriculture
- Religion
- Government, and
- Education

Loss estimation for the general **building stock** is averaged for each census tract. Building damage classifications range from slight to complete. As an example, the building damage classification for wood frame buildings is provided below. Wood-frame structures comprise the most numerous building type in Newport Beach.

Wood, Light Frame:

- *Slight Structural Damage:* Small plaster or gypsum-board cracks at corners of door and window openings and wall-ceiling intersections; small cracks in masonry chimneys and masonry veneer.
- *Moderate Structural Damage:* Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys.
- *Extensive Structural Damage:* Large diagonal cracks across shear wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations; partial collapse of "room-over-garage" or other "soft-story" configurations; small foundations cracks.
- *Complete Structural Damage:* Structure may have large permanent lateral displacement, may collapse, or be in imminent danger of collapse due to cripple wall failure or failure

of the lateral load resisting system; some structures may slip and fall off the foundations; large foundation cracks.

Estimates of building damage are provided for "High", "Moderate" and "Low" seismic design criteria. Buildings of newer construction (e.g., post-1973) are best designated by "High." Buildings built after 1940, but before 1973, are best represented by "Moderate." If built before about 1940 (i.e., before significant seismic codes were implemented), "Low" is most appropriate. A large percentage of buildings in the City of Newport Beach fall in the "Moderate" and "High" seismic design criteria. [In 2006, when the HazUS analysis was conducted, less than 5 percent of the buildings in the City dated from before 1940; about 45 percent dated from between 1940 and 1969; and the rest were built on or after 1970.]

HazUS estimates two types of **debris**. The first is debris that falls in large pieces, such as steel members or reinforced concrete elements. These require special treatment to break into smaller pieces before they are hauled away. The second type of debris is smaller and more easily moved with bulldozers and other machinery and tools. This type includes brick, wood, glass, building contents and other materials.

Casualties are estimated based on the assumption that there is a strong correlation between building damage (both structural and non-structural) and the number and severity of casualties. In smaller earthquakes, non-structural damage will most likely control the casualty estimates. In severe earthquakes where there will be a large number of collapses and partial collapses, there will be a proportionately larger number of fatalities. Data regarding earthquake-related injuries are not of the best quality, nor are they available for all building types. Available data often have insufficient information about the type of structure in which the casualties occurred and the casualty-generating mechanism. HazUS casualty estimates are based on the injury classification scale described in Table 6-4.

Table 6-4: Injury Classification Scale

Injury Severity Level	Injury Description
Severity 1	Injuries requiring basic medical aid without requiring hospitalization.
Severity 2	Injuries requiring a greater degree of medical care and hospitalization, but not expected to progress to a life-threatening status.
Severity 3	Injuries which pose an immediate life-threatening condition if not treated adequately and expeditiously. The majority of these injuries are the result of structural collapse and subsequent entrapment or impairment of the occupants.
Severity 4	Instantaneously killed or mortally injured.

In addition, HazUS produces casualty estimates for **three times of day**:

- Earthquake striking at 2:00 a.m. (population at home)
- Earthquake striking at 2:00 p.m. (population at work/school)
- Earthquake striking at 5:00 p.m. (commute time).

Displaced Households/Shelter Requirements – Earthquakes can cause loss of function or habitability of buildings that contain housing. Displaced households may need alternative short-term shelter, provided by family, friends, temporary rentals, or public shelters established by the City, County or by relief organizations such as the Red Cross. Long-term alternative housing may require import of mobile homes, occupancy of vacant units, net emigration from the impacted area, or, eventually, the repair or reconstruction of new public and private housing. The number of people seeking short-term public shelter is of most concern to emergency response organizations. The longer-term impacts on the housing stock are of great concern to local governments, such as cities and counties.

Economic Losses – HazUS estimates structural and nonstructural repair costs caused by building damage and the associated loss of building contents and business inventory. Building damage can cause additional losses by restricting the building's ability to function properly. Thus, business interruption and rental income losses are estimated. HazUS divides building losses into two categories: (1) direct building losses and (2) business interruption losses. Direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. Business interruption losses are associated with inability to operate a business because of the damage sustained during the earthquake. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the earthquake. HazUS does not calculate business interruption losses due to failure of the lifeline systems (such as electric power outages).

Earthquakes may produce indirect economic losses in sectors that do not sustain direct damage. All businesses are forward-linked (if they rely on regional customers to purchase their output) or backward-linked (if they rely on regional suppliers to provide their inputs) and are thus potentially vulnerable to interruptions in their operation. Note that indirect losses are not confined to immediate customers or suppliers of damaged enterprises. All of the successive rounds of customers of customers and suppliers of suppliers are affected. In this way, even limited physical earthquake damage causes a chain reaction, or ripple effect, that is transmitted throughout the regional economy.

HazUS Scenario Earthquakes for the Newport Beach Area

Four specific scenario earthquakes were modeled using the HazUS loss estimation software available from FEMA: earthquakes on the San Joaquin Hills, Newport-Inglewood, Whittier, and San Andreas faults (see Table 6-5).

The four earthquake scenarios modeled for this study are discussed in the following sections. An earthquake on the San Andreas fault is discussed because it has the highest probability of occurring in the not too distant future, even though the losses expected from this earthquake are not the worst possible for Newport Beach. An earthquake on the San Andreas fault has traditionally been considered the “Big One,” the implication being that an earthquake on this fault would be devastating to southern California. However, there are several other seismic sources that, given their location closer to coastal Orange County, would be more devastating to the region, even if the causative earthquake is smaller in magnitude than an earthquake on the San Andreas fault.

Table 6-5: HazUS Scenario Earthquakes for the City of Newport Beach

Fault Source	EQ Magnitude	Description
San Joaquin Hills	7.1	Potentially worst-case scenario for the City of Newport Beach because this fault's blind thrust geometry could produce greater vertical accelerations than a comparable strike-slip event and vertical motions are more damaging to structures. Note that the San Joaquin Hills fault properties are not well understood and the HazUS results should thus be interpreted with caution.
Newport-Inglewood	6.9	Potentially worst-case scenario for the City of Newport Beach because of the close proximity of this fault. The Newport-Inglewood fault parallels the coast only a few miles offshore of southern Newport Beach and comes onshore directly beneath West Newport.
Whittier	6.8	This fault lies about 22 miles north of the City and could cause significant damage in Newport Beach. The 6.8 magnitude earthquake modeled is in the middle of the size range of earthquakes that researchers now believe this fault is capable of generating.
San Andreas 1857 earthquake	7.8	A large earthquake that ruptures multiple segments of the San Andreas fault is modeled because of its high probability of occurrence, even though the epicenter would be relatively far from the City.

The San Joaquin Hills blind thrust was only discovered in the late 1990s and its geometry and behavior are not well constrained. However, an earthquake on this fault, due to its blind thrust geometry and location, has the potential to be as severe, or more damaging to Newport Beach than rupture of the Newport-Inglewood fault. Typically, earthquakes on thrust faults produce greater vertical accelerations than comparably sized strike-slip earthquakes (such as one on the Newport-Inglewood fault) and vertical motions are more damaging to structures. Scientists have suggested the San Joaquin Hills blind thrust fault could produce a magnitude 6.6 to 7.3 earthquake. We used a mid- to higher-end magnitude of 7.1 for our modeling based on Grant and others' (2002) study that suggests the last earthquake on this fault was greater than a magnitude 7. However, further research is needed to better understand the seismic character of the San Joaquin Hills fault.

Prior to the discovery of the San Joaquin Hills fault, the Newport-Inglewood fault was the only fault thought to pose a strong ground shaking threat to Newport Beach because of its close proximity to the City, its historic activity, and its recurrence interval. Map 6-4 shows that the northern trace of the Newport-Inglewood fault is 2 miles offshore of Reef Point, comes onshore about 1/2 mile southeast of Newport Pier, and crosses directly beneath downtown and West Newport. The Newport-Inglewood fault is also active; it generated the 1933 M_w 6.4 earthquake. The epicenter was located only a mile from Newport Beach, on the western side of the Santa Ana River. This earthquake did not rupture the surface, but substantial liquefaction-induced damage was reported from Long Beach to Huntington Beach. The earthquake caused 120 deaths, and over \$50 million in property damage (Wood, 1933). The Newport-Inglewood fault is also thought to have generated as many as five surface rupturing earthquakes in the past about 11,700 years (Grant et al., 1997; Shlemon et al., 1995).

The Whittier fault is the northern extension of the Elsinore fault and is located approximately 22 miles north of the City of Newport Beach (Map 6-1). No major historical earthquakes have been attributed to the Whittier fault. However, trenching studies have documented recurrent movement of this fault in the past 17,000 years (Gath et al., 1992; Patterson and Rockwell, 1993). Based on these studies, the Whittier fault is thought to be moving at a rate of about 2.5 ± 1 mm/yr. The Southern California Earthquake Center (1995) proposed there is a 5 percent chance of an

earthquake occurring on the Whittier fault by 2024. The Whittier fault is thought capable of producing a magnitude 6.8 maximum magnitude earthquake, although some investigators have proposed an even larger magnitude 7.1 quake. We used the more conservative magnitude 6.8 earthquake in the HazUS model.

We used data from the historic 1857 Fort Tejon earthquake to model the effects of a very large San Andreas earthquake on Newport Beach. Although the 1857 quake nucleated on the Carrizo segment, we place our modeled M 7.8 epicenter closest to Newport Beach (on the San Bernardino segment, the closest segment to Newport Beach) because this will yield the maximum possible damage caused by a San Andreas earthquake.

Inventory Data Used in the HazUS Loss Estimation Models for Newport Beach

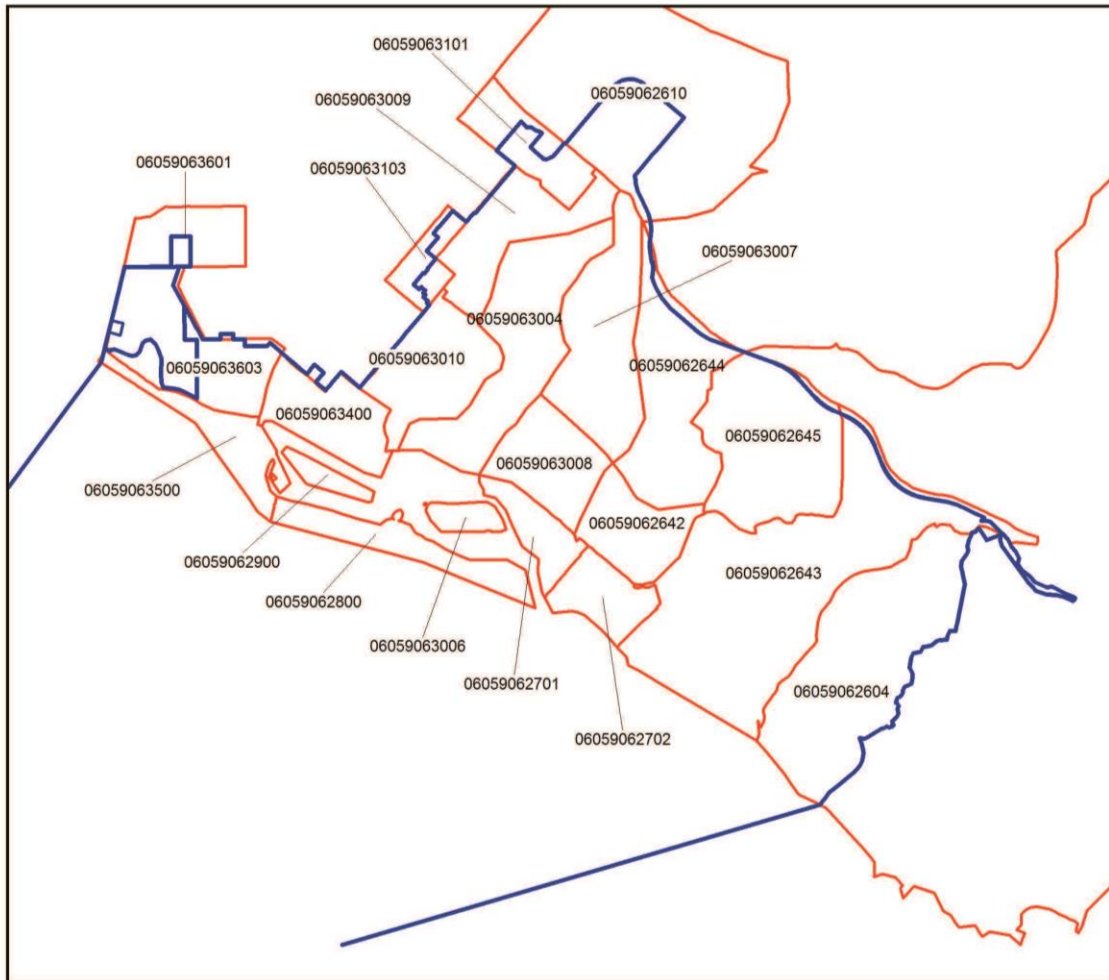
The population data used for the analyses were based on the 2006 American Community Survey data from the U.S. Census Bureau. The general building stock and population inventory data conform to census tract boundaries, and the census tract boundaries generally conform to City limits, with some exceptions. The region studied is about 50.8 square miles in area and contains 22 census tracts. The largest of these census tracts is nearly the same size as all the other census tracts combined, and extends well beyond the City boundary to the southeast and northeast, into an area sparsely populated (Map 6-9). According to the 2006 Census data, there were over 40,000 households in the region, with a total population of 87,955 (this figure includes those areas outside City limits that are part of the census tracts used in the study). The 2006-07 permanent population in Newport Beach was estimated at 84,000, but in the summer, it peaks at approximately 100,000 residents, plus 75,000 to 100,000 visitors. Therefore, although the population numbers used in the analysis are appropriate for the area, depending on the season, higher casualties could be expected for the earthquake scenarios considered. The City's 2012 population was estimated at 87,068 (see Section 2), so the numbers used in the HazUS analysis are still within acceptable range.

According to the HazUS database, in 2006, there were an estimated 38,900 buildings in the region with a total building replacement value (excluding contents) of \$13.15 billion. [The 2010 Census data indicate 44,193 housing units in the City, of which 38,751 are occupied year round.] In terms of building construction types found in the region, wood-frame construction makes up 93 percent of the building inventory. Approximately 97 percent of the buildings (and 69 percent of the building value) are associated with residential housing (see Figure 6-2). The remaining percentage is distributed between the other general building types. The replacement value of the transportation and utility lifeline systems in the City of Newport Beach is estimated at nearly \$609 million and \$39 million, respectively (in 2006 dollars).

The HazUS inventory of unreinforced masonry (URM) buildings included 135 structures in the study area, whereas the 2006 Seismic Safety Commission data indicate there are 127 URMs in Newport Beach. These numbers are in close agreement; therefore we used the URM numbers that HazUS provides. However, we did change the seismic design criteria for all of the URMs in the City from low to moderate to reflect the retrofitting efforts that were accomplished in the late 1990s and early 2000s. It is important to note, however, that retrofitting is typically designed to keep buildings from collapsing, but that structural damage to the building is still possible and expected.

**Map 6-9: Census Tracts Used in the HazUS Analysis (in red)
Compared to the City Boundaries (in blue)**

(Note that the region used in the analysis includes parts of Costa Mesa and Irvine.
The census tract farther south extends beyond the limits of the box)

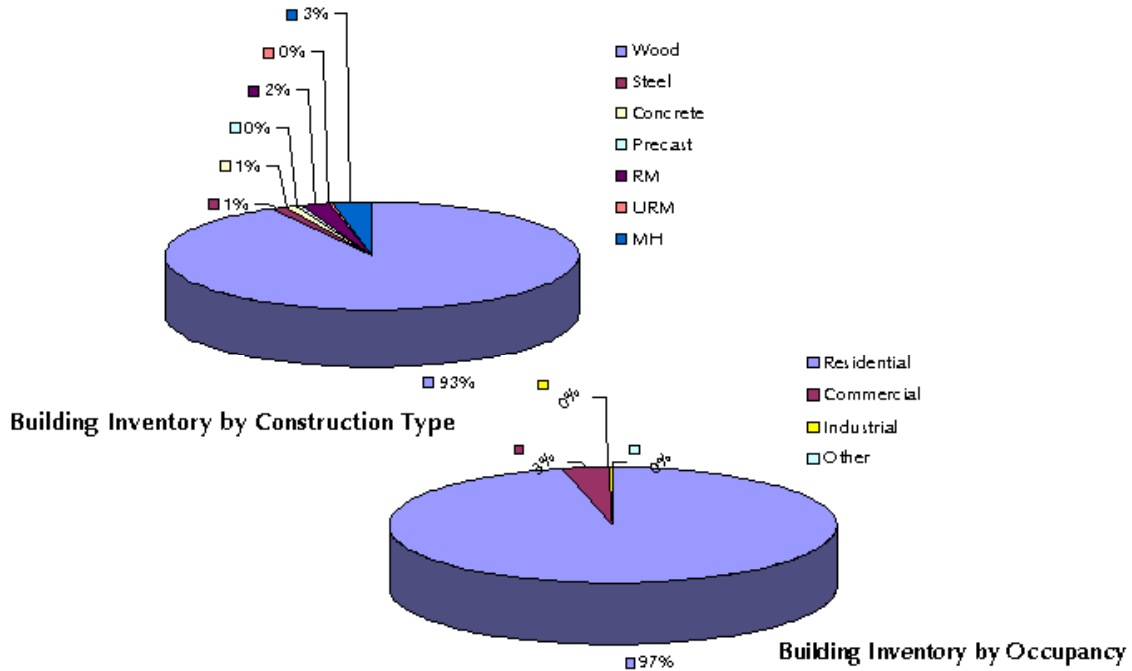


Regarding critical facilities, the HazUS database for the areas considered in the analysis included 28 school facilities (including public and private schools in Newport Beach and portions of Costa Mesa, pre-schools, and the Department of Education offices off of Red Hill Avenue), 8 fire stations, 2 police stations, and one emergency operations center (located in the auditorium of the main police station). [The City's new emergency operations center is located in the basement of the new City Hall.] In the discussion on losses below, however, we refer only to the schools within the City shown on Map 6-10. High potential loss facilities in the area identified in the HazUS database include 4 dams, 3 of which are considered high hazard, and 15 hazardous materials sites. The one hospital in the area, Hoag Memorial Hospital Presbyterian, was modeled with a total bed capacity of 511 beds, although the actual number of beds regularly available is less, as discussed further below.

Hoag Memorial Hospital Presbyterian is a not-for-profit, acute care hospital. Its campus consists of two hospital towers (West Tower and the Sue & Bill Gross Women's Pavilion), the Hoag Heart and Vascular Institute, the Hoag Cancer Center, an ambulatory surgery center (James Irvine Surgical Center), a childcare center and conference center. Fully accredited by the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) and designated as a Magnet hospital by the

American Nurses Credentialing Center (ANCC), Hoag offers a comprehensive mix of health care services, including Centers of Excellence in cancer, heart and vascular, neurosciences, orthopedics and women’s health services.

Figure 6-2
Building Inventory, by Occupancy and Building Type, in the Newport Beach Area
 (values shown are percentages)



Hoag has over 1,000 physicians on staff and has more than 4,000 employees. Hoag sees nearly 25,000 inpatients and 200,000 outpatients annually.

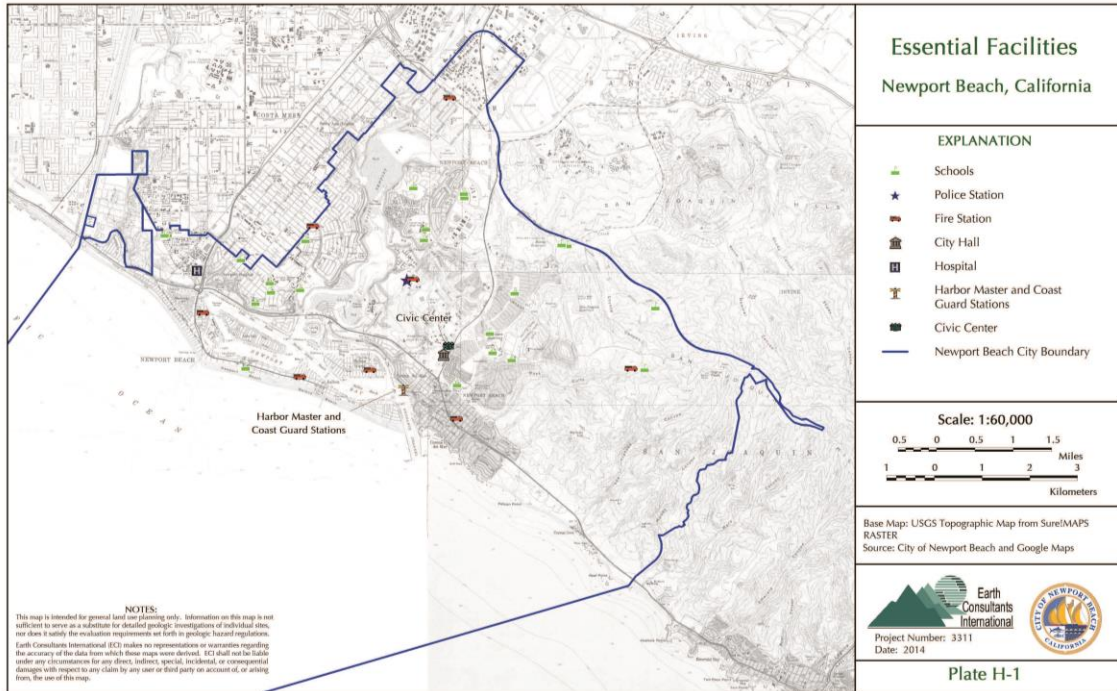
Although licensed for 511 beds, as of April 2007, the number of inpatient available beds was approximately 478 and the number of staffed beds was approximately 417. Inpatient available is an internal definition for beds that are physically available for inpatient use based on Hoag's operational use of bed. This excludes suspended beds and four Labor & Delivery Room (LDR) non-inpatient licensed beds, but includes all other physically available, 24-hour convertible and inpatient licensed beds in use. Staffed beds are defined as operationally available for inpatient use plus all LDR. This is based on Hoag's operational use of bed. Inpatient beds used exclusively for outpatient services or used temporarily for non-patient care (such as a lounge) are not counted in staffed bed numbers. These numbers more closely represent the hospital’s daily capacity in being able to treat increased numbers of victims during a disaster.

Hoag’s emergency care unit has 30 licensed beds and has full victim decontamination capability, including equipment, supplies and trained first receivers. In 2007, the emergency care unit had started a total renovation and expansion that would increase the unit’s bed capacity to 51 total licensed beds. The expected completion date for this renovation was mid-2010 and was the renovation was completed as planned.

The Hoag Hospital campus is supported by an extensive emergency power system. In addition to regular power supplied by Southern California Edison (SCE), the campus is supplemented by a natural-gas-fired cogeneration power plant. Also, a substantial emergency generator plant supports the critical load of the campus and is composed of five (5) 1750 kilowatt generators which is planned to provide power for up to 5 days on normal loads.

Map 6-10: Essential Facilities in Newport Beach (in 2014)
 (for a larger version of this map, refer to Plate H-1 in Appendix H)

The HazUS analysis presented here used the location of the essential facilities as of 2006.



Estimated Losses Associated with the Earthquake Scenarios

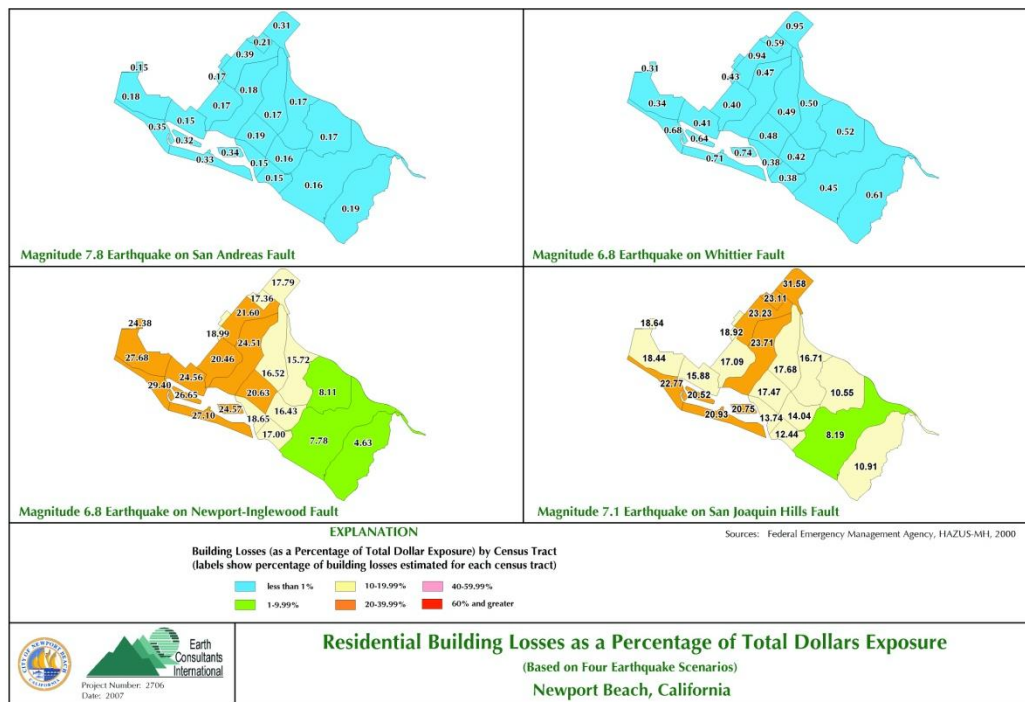
HazUS loss estimations for Newport Beach based on the modeled earthquake scenarios are presented concurrently below. These scenarios include earthquakes on the San Joaquin Hills, Newport-Inglewood, Whittier, and San Andreas faults. Of the four earthquake scenarios modeled for the City, the results indicate that the San Andreas fault poses the least damage to the Newport Beach area, although this fault may have the highest probability of rupturing in the near-future.

Given their proximity, fault type and magnitudes of their maximum earthquake, the San Joaquin Hills and Newport-Inglewood faults both have the potential to cause the worst-case scenario for Newport Beach. The San Joaquin Hills structure is a reverse fault that is thought to be responsible for uplift of the San Joaquin Hills. It may have caused the greater than magnitude 7 earthquake reported by the Portolá expedition in 1769 (Grant et al., 2002). In general, reverse earthquakes generate stronger ground accelerations that are distributed over broader geographic areas than similar-magnitude strike-slip earthquakes. The Newport-Inglewood fault also has the potential to cause significant damage in the City of Newport Beach. The losses anticipated as a result of the Whittier fault causing an earthquake are an order of magnitude lower than the two scenarios just discussed.

Building Damage

HazUS estimates that between approximately 190 and 15,900 buildings will be at least moderately damaged in response to the earthquake scenarios presented herein, with the lower number representative of damage as a result of an earthquake on the San Andreas fault, and the higher number representing damage as a result of an earthquake on the Newport-Inglewood fault. These figures represent about 0.5 to 41 percent of the total number of buildings in the study area. An estimated 1 to 2,910 buildings will be completely destroyed. Table 6-6 summarizes the expected damage to buildings by general occupancy type, whereas Table 6-7 summarizes the expected damage to buildings in the study area classified by construction type. The data presented in Tables 6-6 and 6-7 show that given the large percentage of residential structures, most of the buildings damaged will be residential, with wood-frame structures experiencing mostly slight to moderate damage.

Map 6-1 I: Damage Distribution to Residential Structures as a Result of Four Earthquake Scenarios
 (for a larger version of this map, refer to Plate H-5 in Appendix H)



The San Joaquin Hills fault earthquake scenario has the potential to cause at least slight damage to more than 74 percent of the residential structures in Newport Beach, and moderate to complete damage to as much as 34 percent of the residential stock; whereas, the Newport-Inglewood scenario has the potential to cause at least slight damage to 78 percent of the residential structures in Newport Beach, and moderate to complete damage to approximately 40 percent of the residential stock. The distribution and severity of the damage caused by these earthquakes to the residential buildings in the City is illustrated in Map 6-1 I. The Whittier fault has the potential to cause some damage to the residential stock of Newport Beach, but the damage would not be as severe as that caused by either the San Joaquin Hills or Newport-Inglewood faults. The Whittier fault earthquake scenario is estimated to cause at least slight damage to nearly 10 percent of the

residential stock. The San Andreas fault earthquake scenario is anticipated to cause at least slight damage to about 4 percent of the residential buildings in the City.

Table 6-6: Number of Buildings Damaged, by Occupancy Type

Scenario	Occupancy Type	Slight	Moderate	Extensive	Complete	Total
San Joaquin Hills	Residential	14,953	8,955	1,416	2,500	27,824
	Commercial	271	403	223	137	1,034
	Industrial	21	38	25	16	85
	Agriculture	0	0	0	0	0
	Religion	5	7	3	2	17
	Government	2	4	2	2	10
	Education	1	1	0	0	2
	Total	15,253	9,408	1,669	2,567	28,972
Newport-Inglewood	Residential	14,282	10,392	1,915	2,770	29,359
	Commercial	280	387	201	126	994
	Industrial	25	36	18	11	90
	Agriculture	0	0	0	0	0
	Religion	5	6	3	2	16
	Government	3	3	2	1	9
	Education	1	0	0	0	1
	Total	14,596	10,824	2,139	2,910	30,469
Whittier	Residential	3,156	396	22	3	3,577
	Commercial	101	41	5	0	147
	Industrial	11	5	1	0	17
	Agriculture	0	0	0	0	0
	Religion	2	1	0	0	3
	Government	1	0	0	0	1
	Education	0	0	0	0	0
	Total	3,271	443	28	3	3,745
San Andreas	Residential	1,447	159	9	1	1,616
	Commercial	53	18	2	0	73
	Industrial	6	2	0	0	8
	Agriculture	0	0	0	0	0
	Religion	1	0	0	0	1
	Government	1	0	0	0	1
	Education	0	0	0	0	0
	Total	1,508	179	11	1	1,699

The commercial and industrial structures in Newport Beach will also be impacted (Table 6-6). The San Joaquin Hills and Newport-Inglewood earthquakes have the potential to cause at least moderate damage to about 63 and 59 percent, respectively, of the combined commercial and industrial buildings in the City. The distribution and severity of damage to the commercial structures in the City as a result of earthquakes on the San Joaquin Hills, Newport-Inglewood (NIFZ), Whittier and San Andreas faults is illustrated in Map 6-12. All four earthquakes shown on Map 6-12 are anticipated to cause at least some damage in the commercial district of the City, but an earthquake on the San Joaquin Hills fault would be the more regionally severe, given the fault’s type and location

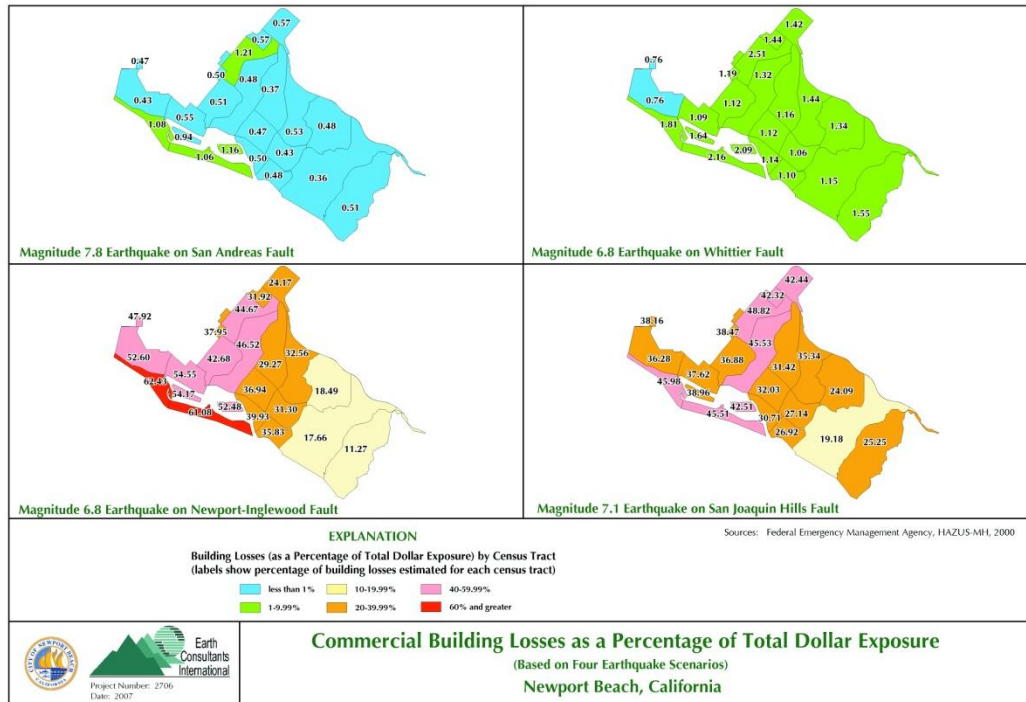
beneath the heart of Newport Beach. An earthquake on the NIFZ would cause extensive damage to the commercial structures in the Balboa Peninsula and West Newport areas.

Table 6-7: Number of Buildings Damaged, by Construction Type

Scenario	Structure Type	Slight	Moderate	Extensive	Complete	Total
San Joaquin Hills	Concrete	100	120	68	46	334
	Mobile Homes	167	422	361	171	1,121
	Precast Concrete	32	68	47	27	174
	Reinforced Masonry	164	256	149	78	647
	Steel	77	150	95	57	379
	URM (Retrofitted)	20	46	33	28	127
	Wood	14,693	8,346	916	2,250	26,205
	Total	15,253	9,408	1,669	2,657	28,987
Newport-Inglewood	Concrete	96	120	69	50	335
	Mobile Homes	153	379	360	218	1,110
	Precast Concrete	36	65	40	22	163
	Reinforced Masonry	154	255	161	86	656
	Steel	76	145	94	59	374
	URM (Retrofitted)	19	43	33	31	126
	Wood	14,062	9,817	1,382	2,444	27,705
	Total	14,596	10,824	2,139	2,910	30,469
Whittier	Concrete	37	12	1	0	50
	Mobile Homes	180	111	14	0	305
	Precast Concrete	18	10	1	0	29
	Reinforced Masonry	48	24	3	0	75
	Steel	43	22	2	0	67
	URM (Retrofitted)	21	10	2	1	34
	Wood	2,924	254	5	2	3,184
	Total	3,271	443	28	3	3,744
San Andreas	Concrete	19	5	0	0	24
	Mobile Homes	118	64	7	0	189
	Precast Concrete	9	4	0	0	13
	Reinforced Masonry	25	10	1	0	36
	Steel	25	11	1	0	37
	URM (Retrofitted)	14	5	1	1	21
	Wood	1,298	80	1	0	1,379
	Total	1,508	179	11	1	1,699

The HazUS output shows that the retrofitted URMs in Newport Beach will suffer slight to complete damage, with up to 21 percent likely to be completely destroyed during an earthquake on the San Joaquin Hills fault, and up to 23 percent destroyed by an earthquake on the Newport-Inglewood fault. At first glance these numbers seems high, however, it is likely that most of the URMs would have collapsed during these scenarios if they had not been retrofitted. The numbers show that by retrofitting its URMs, Newport Beach has already reduced its vulnerability to seismic shaking, and as a result, its potential number of earthquake-induced casualties.

Map 6-12: Damage Distribution to Commercial Structures as a Result of Four Earthquake Scenarios



Significantly, reinforced masonry, concrete and steel structures are not expected to perform well, with hundreds of these buildings in Newport Beach experiencing at least moderate damage during an earthquake on the San Joaquin Hills or Newport-Inglewood faults. These types of structures are commonly used for commercial and industrial purposes, and failure of some of these structures explains the casualties anticipated during the middle of the day in the non-residential sector (see Table 6-8). These types of buildings also generate heavy debris that is difficult to cut through to extricate victims.

Casualties

Table 6-8 provides a summary of the casualties estimated for these scenarios. The analysis indicates that the worst time for an earthquake to occur in the City of Newport Beach is during maximum non-residential occupancy (at 2 o'clock in the afternoon, when most people are in their place of business and schools are in session). The San Joaquin Hills earthquake scenario is anticipated to cause the largest number of casualties, followed closely by an event on the Newport-Inglewood fault. Although still significant, given the number of estimated injuries and deaths, the model indicates that the safest time for an earthquake to occur in Newport Beach is during maximum residential occupancy at 2 o'clock in the morning, when most people are at home. These findings reflect the generally good performance of residential structures to strong ground shaking – houses may be damaged but for the most part are not expected to collapse. Both the Whittier and San Andreas fault scenarios are anticipated to result in only a few non-life threatening injuries.

Table 6-8: Estimated Casualties

Type and Time of Scenario			Level 1:	Level 2:	Level 3:	Level 4:
			Medical treatment without hospitalization	Hospitalization but not life threatening	Hospitalization and life threatening	Fatalities due to scenario event
San Joaquin Hills	2 A.M. (max. residential occupancy)	Residential	476	112	9	15
		Non-Residential	63	18	3	6
		Commute	0	0	0	0
		Total	539	130	12	21
	2 P.M. (max educational, industrial, and commercial)	Residential	85	20	2	2
		Non-Residential	1,620	469	76	151
		Commute	1	1	1	0
		Total	1,706	490	79	153
	5 P.M. (peak commute time)	Residential	188	44	4	6
Non-Residential		957	276	45	87	
Commute		69	87	155	29	
Total		1,214	407	202	122	
Newport-Inglewood	2 A.M. (max. residential occupancy)	Residential	533	125	10	18
		Non-Residential	48	13	2	4
		Commute	0	0	0	0
		Total	581	138	12	22
	2 P.M. (max educational, industrial, and commercial)	Residential	95	22	2	3
		Non-Residential	1,314	377	60	120
		Commute	1	1	2	0
		Total	1,410	400	64	123
	5 P.M. (peak commute time)	Residential	211	49	4	7
Non-Residential		790	226	37	71	
Commute		41	51	91	17	
Total		1,042	326	132	95	
Whittier	2 A.M. (max. residential occupancy)	Residential	8	1	0	0
		Non-Residential	0	0	0	0
		Commute	0	0	0	0
		Total	8	1	0	0
	2 P.M. (max educational, industrial, and commercial)	Residential	1	0	0	0
		Non-Residential	25	3	0	0
		Commute	0	0	0	0
		Total	26	3	0	0
	5 P.M. (peak commute time)	Residential	2	0	0	0
Non-Residential		16	2	0	0	
Commute		0	1	0	0	
Total		18	2	1	0	
San Andreas	2 A.M. (max. residential occupancy)	Residential	3	0	0	0
		Non-Residential	0	0	0	0
		Commute	0	0	0	0
		Total	3	0	0	0
	2 P.M. (max educational, industrial, and commercial)	Residential	0	0	0	0
		Non-Residential	11	1	0	0
		Commute	0	0	0	0
		Total	11	1	0	0
	5 P.M. (peak commute time)	Residential	1	0	0	0
Non-Residential		7	1	0	0	
Commute		0	0	1	0	
Total		8	1	1	0	

Essential Facility Damage

The loss estimation model calculates the percentage of hospital beds in Newport Beach that will be available after each earthquake scenario.

A maximum magnitude earthquake on the San Joaquin Hills fault is expected to impact Hoag Memorial Hospital such that 54 percent of the beds would be damaged and unavailable for relief efforts, leaving only 46 percent of the hospital beds available on the day of the earthquake for use by existing patients (those already in the hospital) and by injured persons requiring hospitalization. One week after the earthquake, about 86 percent of the beds are expected to be back in service. After one month, 95 percent of the beds are expected to be operational.

On the day of the Newport-Inglewood earthquake, the model estimates that only about 114 hospital beds (22 percent, using 511 beds for the calculation) will be available for use by patients already in the hospital and those injured by the earthquake. After one week, 73 percent of the beds will be back in service. After thirty days, 93 percent of the beds will be available for use.

An earthquake on the Whittier fault is significantly better regarding the availability of hospital beds. The model estimates that 99 percent of the hospital beds will be available on the day of the earthquake. After one week, 100 percent of the hospital beds are expected to be available for use. Similarly, an earthquake on the San Andreas fault is not expected to cause damage to Hoag Memorial Hospital. On the day of the earthquake, the model estimates that 99 percent of the beds will be available for use; after one week, 100 percent of the beds will be available for use.

Given that the models estimate that about 600 people in the Newport Beach area will require hospitalization after an earthquake on the San Joaquin Hills fault (see Table 6-8), Hoag Memorial Hospital is not expected to have enough beds to meet the demand for medical care (the model estimates about 236 beds will be available at this hospital after the scenario earthquake, and that number includes beds occupied by patients already at the hospital when the earthquake strikes). Similarly, the hospital is not expected to be able to provide medical attention to all the people needing medical assistance after an earthquake on the segment of the Newport-Inglewood fault within or adjacent to Newport Beach. However, nearby cities, such as Irvine, Santa Ana, Mission Viejo and Fountain Valley may sustain less damage and people requiring hospitalization could be treated at medical facilities in these cities. The model estimates that there would be sufficient beds available to treat patients injured during an earthquake on either the Whittier or San Andreas fault.

HazUS also estimates the damage to other critical facilities in the City, including schools, fire and police stations, and the emergency operations center. According to the model, earthquakes on the San Andreas and Whittier faults will cause only slight damage to the schools, fire and police stations, and the City's emergency operations center. All of these facilities are expected to be more than 50 percent functional the day after the earthquake.

An earthquake on the San Joaquin Hills fault is anticipated to cause at least moderate damage to all schools in the City, and none of the schools and school district offices in the study area are expected to be more than 50 percent operational seven days after the earthquake. The model also indicates that Hoag Memorial Hospital, the police stations, the emergency operations center, and 7 of the 8 fire stations will experience more than slight damage, and that none of these facilities will be more than 50 percent operational the day after the earthquake. [Given that the City's emergency operations center is located at the new City Hall, its functionality after an earthquake is expected to be much better than what the HazUS analysis estimated.]

Similarly, an earthquake on the Newport-Inglewood fault is anticipated to cause at least moderate damage to all schools in the City. The model also shows that Hoag Memorial Hospital and one of the fire stations will experience more than slight damage, with the hospital, the emergency operations center, and the police and fire stations all less than 50 percent operational the day after the earthquake. [Again, the emergency operations center has been moved to a new, earthquake-resistant structure, so its functionality after an earthquake is expected to be much better than this, as the HazUS model is referring to the older location.] The modeled earthquakes on the Whittier and San Andreas faults will not damage or cause delays to any of the critical facilities in the City of Newport Beach.

Building-Related Losses

Total economic losses include building- and lifeline-related losses based on the region’s available inventory. Direct building losses (or capital stock losses in Table 6-9) are the estimated costs to repair or replace the damage caused to the buildings and its contents. It includes structural and non-structural damage to the building itself, and damage to the contents, and in the case of businesses, damage to inventory. Income losses, or business interruption losses, are losses associated with the inability to operate a business because of the damage it sustained during the earthquake. Income loss estimates also include the temporary living expenses for those people displaced from their homes because of the earthquake. Income losses, however, do not include losses related to the inability to operate the business because of lifeline outages or damage to the transportation network limiting access to a business.

The model estimates that total building-related losses in the City of Newport Beach will range from less than \$42 million for an earthquake on the San Andreas fault, to \$3,120 million for an earthquake on the San Joaquin Hills fault. Approximately 13 percent of these estimated losses would be related to business interruption in the City. Damage to residential occupancies accounts for the largest loss, ranging from about 45 to 55 percent of the total building-related economic loss estimates. Table 6-9 below provides a summary of the estimated economic losses anticipated as a result of each of the earthquake scenarios considered herein. The total economic losses to the region include the costs of repairing or replacing the damaged lifeline systems. This is discussed further below.

Table 6-9: Building-Related Economic Loss Estimates (in Million \$)

Scenario	Capital Stock Losses				Income Losses				Total
	Residential	Commercial	Industrial	Other	Residential	Commercial	Industrial	Other	
San Joaquin Hills	1,507.57	1,002.12	150.83	53.34	71.64	325.17	6.34	3.41	3,120.42
Newport-Inglewood	1,698.05	869.97	113.74	42.57	76.25	300.35	4.82	2.7	3,108.44
Whittier	45.69	33.59	5.94	1.89	1.38	10.89	0.27	0.11	99.76
San Andreas	18.55	14.44	2.58	0.76	0.49	4.85	0.11	0.04	41.81

Shelter Requirement

HazUS estimates that nearly 3,694 households in Newport Beach may be displaced due to the San Joaquin Hills earthquake modeled for this study. About 741 people will seek temporary shelter in public shelters. The rest of the displaced individuals are anticipated to seek shelter with family or friends. An earthquake on the Newport-Inglewood fault is anticipated to displace over 4,153 households, with approximately 835 people seeking temporary shelter. The San Andreas and Whittier earthquakes are expected to displace none to very few households.

Table 6-10: Estimated Shelter Requirements

Scenario	Displaced Households	People Needing Short-Term Shelter
San Joaquin Hills	3,694	741
Newport-Inglewood	4,153	835
Whittier	0	0
San Andreas	6	1

Transportation Damage

Damage to the transportation system in the City of Newport Beach is based on a generalized inventory of the region, which includes areas outside of the City since the transportation network extends beyond corporate boundaries. Road segments are assumed to be damaged by ground failure only; therefore, the numbers presented herein may be low given that, based on damage observed from the Northridge and San Fernando earthquakes, strong ground shaking can cause considerable damage to bridges.

The San Joaquin Hills fault earthquake scenario is the worst-case for the transportation system in the City. Economic losses to the region due to bridge damage are estimated at between \$0.5 million (for an earthquake on either the San Andreas or Whittier fault) to \$27.35 million for an earthquake on the San Joaquin Hills fault (see Table 6-11). The HazUS analysis suggests that as many as twelve bridges would be damaged by an earthquake on the San Joaquin Hills fault; ten of these would experience at least moderate damage, and one bridge would be completely damaged. An earthquake on the Newport-Inglewood fault would cause at least moderate damage to five bridges, and one of these would be completely damaged. Neither the Whittier nor the San Andreas fault earthquake scenarios are expected to cause more than slight damage to the bridges in the area, and all bridges are expected to be more than 50 percent functional the first day after the earthquake. Although the road segments that traverse the area are anticipated to experience some damage, none of them will be significantly impaired, as they are all expected to be more than 50 percent functional the next day.

These loss estimates are a substantial improvement over loss estimates performed in 2003 that indicated losses of between \$3.1 million for an earthquake on the San Andreas fault, and \$57.4 million for an earthquake on the San Joaquin Hills fault. These improvements reflect the recent seismic upgrades and retrofitting that the City and Caltrans have undertaken for bridges in the region. Nevertheless, there are still 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.

John Wayne Airport is expected to incur losses of between about \$0.29 million (for an earthquake on the San Andreas fault) and \$5.34 million (for an earthquake on the San Joaquin Hills fault). In all scenarios, however, airport functionality will not be greatly impaired.

Table 6-11: Damage to the Transportation System

EQ Scenario	System	Segments in Inventory	Replacement Value (\$Million)	With at Least Moderate Damage	With Complete Damage	Economic Loss (\$Million)	>50% Functional After Day 1	
San Joaquin Hills	Highway	Segments	7	294.64	0	0	7.22	7
		Bridges	58	232.39	10	1	27.35	46
	Airport	Facilities	1	2.57	1	0	1.07	1
		Facilities	1	6.43	1	0	3.82	1
		Runway	2	73.35	0	0	1.52	2
Newport-Inglewood	Highway	Segments	7	294.64	0	0	5.57	7
		Bridges	58	232.39	4	1	18.84	54
	Airport	Facilities	1	2.57	0	0	1.18	1
		Facilities	1	6.43	1	0	2.35	1
		Runway	2	73.35	0	0	0.16	2
Whittier	Highway	Segments	7	294.64	0	0	0	7
		Bridges	58	232.39	0	0	0.45	58
	Airport	Facilities	1	2.57	0	0	0.11	1
		Facilities	1	6.43	0	0	0.5	1
		Runway	2	73.35	0	0	0	2
San Andreas	Highway	Segments	7	294.64	0	0	0	7
		Bridges	58	232.39	0	0	0.47	58
	Airport	Facilities	1	2.57	0	0	0.06	1
		Facilities	1	6.43	0	0	0.29	1
		Runway	2	73.35	0	0	0	2

Utility Systems Damage

The HazUS inventory for the Newport Beach area does not include specifics regarding the various lifeline systems in the City, therefore, the model estimated damage to the potable water and electric power using empirical relationships based on the number of households served in the area. The results of the analyses regarding the functionality of the potable water and electric power systems in the City for the four earthquakes discussed herein are presented in Table 6-12. According to the models, the San Joaquin Hills and Newport-Inglewood earthquake scenarios will severely impact the electric power systems; thousands of households in the City are expected to not have electric power even three days after an earthquake on either of these faults. An earthquake on the San Joaquin Hills fault is anticipated to leave more than 7,000 households without electricity for more than one week, whereas an earthquake on the Newport-Inglewood fault would leave about 9,000 without electricity for one week, and up to 2,000 without power for one month.

The potable water system is expected to do better, but both the San Joaquin Hills fault and Newport-Inglewood fault earthquake scenarios have the potential of leaving thousands without potable water for at least 3 days after the earthquake. These results suggest that the City will have

to truck in water to some of the residential neighborhoods until the damages to the water system are repaired. Residents are advised to have drinking water stored as part of their earthquake emergency kits, enough to last all members of the household (including pets) at least 3 days, and preferably one week.

Table 6-12: Expected Performance of Potable Water and Electricity Services

Scenario	Utility	Number of Households without Service*				
		Day 1	Day 3	Day 7	Day 30	Day 90
San Joaquin Hills	Potable Water	22,986	6,360	0	0	0
	Electricity	28,742	17,485	7,176	1,488	41
Newport-Inglewood	Potable Water	26,219	12,315	0	0	0
	Electricity	29,394	19,327	8,986	2,137	39
Whittier	Potable Water	0	0	0	0	0
	Electricity	0	0	0	0	0
San Andreas	Potable Water	0	0	0	0	0
	Electricity	0	0	0	0	0

*Based on Total Number of Households = 40,706.

Table 6-13: Expected Utility Systems Pipeline Damage

Scenario	System	Total Pipelines Length (km)	Number of Leaks	Number of Breaks
San Joaquin Hills	Potable Water	690	179	104
	Waste Water	414	142	82
	Natural Gas	276	152	88
	Oil	0	0	0
Newport-Inglewood	Potable Water	690	192	119
	Waste Water	414	152	94
	Natural Gas	276	162	101
	Oil	0	0	0
Whittier	Potable Water	690	8	2
	Waste Water	414	7	2
	Natural Gas	276	7	2
	Oil	0	0	0
San Andreas	Potable Water	690	10	3
	Waste Water	414	8	2
	Natural Gas	276	8	2
	Oil	0	0	0

Fire Following Earthquake

History shows that earthquake-induced fires have the potential to be the worst-case fire-suppression scenarios for a community because an earthquake typically causes multiple ignitions distributed over a broad geographic area, with the potential to severely tax the local fire suppression agencies. Furthermore, if fire fighters are involved with search and rescue operations, they are less available to fight fires. Fire suppression efforts can also be limited by a water

distribution system that has been impaired by the earthquake. Thus, many factors affect the severity of fires following an earthquake, including ignition sources, types and density of fuel, weather conditions, functionality of the water systems, and the ability of firefighters to suppress the fires. The principal causes of earthquake-related fires are open flames, electrical malfunctions, gas leaks, and chemical spills. Downed power lines may ignite fires if the lines do not automatically de-energize. Unanchored gas heaters and water heaters have in the past been common problems, as these readily tip over during strong ground shaking; State law requires new and replaced gas-fired water heaters to be attached to a wall or other support.

The major urban conflagrations of former times in major cities were often the result of closely built, congested areas of attached buildings with no fire sprinklers, no adequate fire separations, no Fire Code enforcement, and narrow streets. In the past, fire apparatus and water supplies were also inadequate in many large cities, and many fire departments were comprised of volunteers. Many of these conditions no longer apply to the cities of today. Nevertheless, major earthquakes can result in fires and the loss of water supply, as it occurred in San Francisco in 1906, and in Kobe, Japan in 1995. A large portion of the structural damage caused by the great San Francisco earthquake of 1906 was the result of fires rather than ground shaking.

The moderately sized, M6.7 Northridge earthquake of 1994 caused 15,021 natural gas leaks that resulted in three street fires, 51 structure fires (23 of these caused total ruin) and the destruction, by fire, of 172 mobile homes. The 51 structure fires were caused by overturned water heaters (20), other overturned or damaged gas appliances (8), broken interior gas lines (8), broken gas meter set assemblies (2), street fires due to breaks in gas mains (7), and other unknown causes (8). The mobile home fires were primarily the result of failure of the supports leading to breakage of the gas risers, and breakage of the interior gas lines due to overturned water heaters and other appliances (Savage, 1995). The Southern California Gas Company reported 35 breaks in its natural gas transmission lines and 717 breaks in its distribution lines. About 74 percent of the leaks were corrosion related. In one incident, the earthquake severed a 22-inch gas transmission line and a motorist ignited the gas while attempting to restart his stalled vehicle. Response to this fire was impeded by the earthquake's rupture of a water main; as a result, five nearby homes were destroyed. Elsewhere, one mobile home fire started when a ruptured transmission line was ignited by a downed power line. In many of the destroyed mobile homes, fires erupted when inadequate bracing allowed the houses to slip off their foundations, severing gas lines and igniting fires.

A regional earthquake scenario that involves rupture of the entire southern section of the San Andreas fault was conducted in 2008 for the ShakeOut Scenario (Jones and others, 2008; Scawthorn, 2008). The scenario estimates that as a result of a magnitude 7.8 earthquake on the southern San Andreas, a total of 206 ignitions would occur in Orange County. This estimate does not include ignitions that are suppressed by responding citizens. Of the estimated 206 ignitions that will require fire department response, 165 would develop into large fires, each requiring the response of more than one fire engine company. The estimated ultimate burnt area in the County would be equivalent to about 37,000 single-family dwellings (Scawthorn, 2008). Using the 1994 Northridge earthquake as proxy, about half of the ignitions are expected to be electric related, about a quarter would be gas related, and the rest would be the result of a variety of causes, including chemical reactions. Also based on the Northridge earthquake, about 70 percent of all ignitions will occur in residential structures. Although city-specific estimates were not computed as part of the ShakeOut scenario, the data clearly highlight the hazard associated with earthquake-induced fires. Response to these fires will be hindered by a damaged water distribution system, overwhelmed local fire department resources, overwhelmed 911 centers, and extremely delayed response from strike teams coming in from outlying areas due to damage to the transportation system and traffic disruption (Scawthorn, 2008).

HazUS uses a Monte Carlo simulation model to estimate the number of ignitions and the amount of burnt area as a result of an earthquake. For the earthquake scenarios ran for Newport Beach, HazUS estimates between 16 and 2 ignitions immediately following an earthquake, with the San Andreas fault earthquake scenario triggering 2 ignitions, the Whittier fault causing 3 ignitions, the Newport-Inglewood causing 16 ignitions and the San Joaquin Hills faults triggering 15 ignitions (Table 6-14). The burnt area resulting from these ignitions will vary depending on wind conditions. Normal wind conditions of about 10 miles per hour (mph) are expected to result in burn areas of between 3 and 100 acres. If Santa Ana wind conditions are present at the time of the earthquake, the burnt areas can be expected to be significantly larger. Additional information regarding fires after earthquakes and the resultant losses estimated for the City of Newport Beach are provided in Section 8.

Table 6-14: Fires Following an Earthquake

EQ Scenario	No. of Ignitions	Approximate Burn Area (Acres)	No. of Displaced Individuals	Building Value Destroyed (Million \$)
San Joaquin Hills	15	70	416	52.75
Newport-Inglewood	16	100	707	88.08
Whittier	3	3	40	4.52
San Andreas	2	6	99	11.31

Debris Generation

The model estimates that between 9 and 889 thousand tons of debris will be generated by the earthquake scenarios considered in this study (see Table 6-15). Of the total amount, brick and wood comprise between 32 and 44 percent of the total, with the remainder consisting of reinforced concrete and steel. If the debris tonnage is converted to an estimated number of truckloads, it will require 360 to 35,560 truckloads (assuming 25 tons per truck) to remove the debris generated by the earthquakes modeled.

Table 6-15: Debris Generated by Earthquake Scenarios

EQ Scenario	Brick/Wood (1000s Tons)	% Total	Reinforced Concrete/Steel (1000s Tons)	% Total	Total	No. of Truckloads
San Joaquin Hills	284	31.95	605	68.05	889	35,560
Newport-Inglewood	289.5	34.55	548.5	65.45	838	33,520
Whittier	9.5	43.18	12.5	56.82	22	880
San Andreas	4	44.44	55.56	55.56	9	360

Existing Mitigation Activities

Existing mitigation activities include current mitigation programs and activities that are being implemented by county, regional, State, or Federal agencies or organizations.

California Earthquake Mitigation Legislation

California is painfully aware of the threats it faces from earthquakes. Since the 1800s, Californians have been killed, injured, and lost property as a result of earthquakes. As the State’s population continues to grow, and urban areas become even more densely built up, the risk will continue to increase. In response to this concern, for decades now the Legislature has passed laws to

strengthen the built environment and protect the citizens. Table 6-16 provides a sampling of some of the 200 plus laws in the State’s codes.

Table 6-16: Partial List of the Over 200 California Laws on Earthquake Safety

CA-1 Field Act (Education Code §17281, et seq.)	Establishes regulation for the design and construction of K-12 and community colleges to ensure seismic safety in new public schools.
CA-2 Riley Act	Requires local governments to have building departments that issue permits for new construction and alterations to existing structures. Set minimum seismic safety requirements that have since been incorporated into all building codes.
CA-5 Seismic Safety General Plan Element (Government Code § 65302)	Requires cities and counties to include seismic safety elements in their general plans. The seismic safety element later became part of the safety element.
Government Code Section 8870-8870.95	Creates Seismic Safety Commission.
Government Code Section 8876.1-8876.10	Established the California Center for Earthquake Engineering Research.
Public Resources Code Section 2800-2804.6	Authorized a prototype earthquake prediction system along the central San Andreas fault near the city of Parkfield.
Public Resources Code Section 2810-2815	Continued the Southern California Earthquake Preparedness Project and the Bay Area Regional Earthquake Preparedness Project.
Health and Safety Code Section 16100-16110	The Seismic Safety Commission and State Architect will develop a state policy on acceptable levels of earthquake risk for new and existing state-owned buildings.
Government Code Section 8871-8871.5	Established the California Earthquake Hazards Reduction Act of 1986.
Health and Safety Code Section 130000-130025	Defined earthquake performance standards for hospitals.
Public Resources Code Section 2805-2808	Established the California Earthquake Education Project.
Government Code Section 8899.10-8899.16	Established the Earthquake Research Evaluation Conference.
Public Resources Code Section 2621-2630 2621.	Established the Alquist-Priolo Earthquake Fault Zoning Act.
Government Code Section 8878.50-8878.52 8878.50.	Created the Earthquake Safety and Public Buildings Rehabilitation Bond Act of 1990.
Education Code Section 35295-35297 35295.	Established emergency procedure systems in kindergarten through grade 12 in all the public or private schools.
Health and Safety Code Section 19160-19169	Established standards for seismic retrofitting of unreinforced masonry buildings.
Health and Safety Code Section 1596.80-1596.879	Required all child day care facilities to include an Earthquake Preparedness Checklist as an attachment to their disaster plan.

City of Newport Beach Codes

Implementation of earthquake mitigation policy most often takes place at the local government level. The City of Newport Beach Community Development Department, Building Division enforces building codes pertaining to earthquake hazards. The City has adopted the provisions of the 2013 California Building Code, a modification to the 2012 Uniform Building Code with more restrictive amendments based upon the local geographic, topographic and climatic conditions. The City of Newport Beach, along with dozens of other local jurisdictions, have worked together to make these amendments to the California Building Code consistent with the rest of southern California. Currently, Newport Beach’s Building Division staff are very active in the code development process

and all regional activities to improve the technical provisions of the building code and the understanding of the purpose of the building codes by the public.

The City of Newport Beach Planning Division enforces the zoning and land use regulations relating to earthquake hazards. Generally, these codes and regulations seek to discourage development in areas that could be prone to flooding, landslide, wildfire and/or seismic hazards; and where development is permitted, that the applicable construction standards are met. Developers in hazard-prone areas may be required to retain a qualified professional engineer to evaluate level of risk on the site and recommend appropriate mitigation measures.

Extensive information about the City's departments, codes and policies, forms and handouts, bulletins, forms required for permit applications, fees, etc., are available from the City's website at <http://www.newportbeachca.gov/>. Look for the link to the City's departments, and then refer to the Building Division section. Building Division staff is also available to help in person at City Hall.

Businesses/Private Sector

Natural hazards have a devastating impact on businesses. In fact, according to the Institute for Business and Home Safety (IBHS), approximately 25 percent of all businesses do not reopen following a major disaster. Business owners and homeowners alike can protect their investment by identifying the risks associated with the natural and man-made disasters that their area is susceptible to (which this plan covers), and then creating and implementing an action plan that defines the steps to take should a disaster strike. To help business owners with this effort, the IBHS has developed "Open for Business," a disaster planning toolkit to help guide businesses in preparing for and dealing with the adverse affects natural hazards (available from <https://www.disastersafety.org/open-for-business/>). The kit integrates protection from natural disasters into the company's risk reduction measures to safeguard employees, customers, and the investment itself. The guide helps businesses secure human and physical resources during disasters, and helps to develop strategies to maintain business continuity before, during, and after a disaster occurs. The U.S. Small Business Administration also provides helpful information and checklists that can be used for this purpose (<http://www.sba.gov/content/disaster-planning>).

Hospitals

The Alfred E. Alquist Hospital Seismic Safety Act ("Hospital Act") was enacted in 1973 in response to the moderate Magnitude 6.6 Sylmar Earthquake in 1971 when four major hospital campuses were severely damaged and evacuated. Two hospital buildings collapsed killing forty seven people. Three others were killed in another hospital that nearly collapsed.

In approving the Act, the Legislature noted that: "Hospitals, that house patients who have less than the capacity of normally healthy persons to protect themselves, and that must be reasonably capable of providing services to the public after a disaster, shall be designed and constructed to resist, insofar as practical, the forces generated by earthquakes, gravity and winds." (Health and Safety Code Section 129680).

When the Hospital Act was passed in 1973, the State anticipated that, based on the regular and timely replacement of aging hospital facilities, the majority of hospital buildings would be in compliance with the Act's standards within 25 years. However, hospital buildings were not, and are not, being replaced at that anticipated rate. In fact, the great majority of the State's urgent care facilities are now more than 40 years old.

The moderate magnitude 6.7 Northridge Earthquake in 1994 caused \$3 billion in hospital-related damage and evacuations. Twelve hospital buildings constructed before the Act were cited (red

tagged) as unsafe for occupancy after the earthquake. Those hospitals that had been built in accordance with the 1973 Hospital Act were successful in resisting structural damage. However, nonstructural damage (for example, plumbing and ceiling systems) was still extensive in those post-1973 buildings.

Senate Bill 1953 (SB 1953), enacted in 1994 after the Northridge earthquake, expanded the scope of the 1973 Hospital Act. Under SB 1953, all hospitals were required by January 1, 2008 to survive earthquakes without collapsing or posing the threat of significant loss of life (life safety level). Provisions were made to allow this deadline to be extended to January 1, 2013 if compliance by the 2008 deadline would result in diminished capacity of healthcare services to the community. Subsequent amendments have provided for additional extensions, with the final date by which all hospitals must comply with the provisions of the act being January 1, 2020. To grant an extension to a hospital, the Office of Statewide Health Planning and Development (OSHPD) must consider the structural integrity of the building, the loss of essential healthcare services to the community if the hospital closed, and the financial hardship that the hospital would experience in complying with the provisions of the Act. The 1994 Act further mandates that all existing hospitals be seismically evaluated, and retrofitted, if needed, by 2030, so that they are in substantial compliance with the Act (which requires that the hospital buildings be reasonably capable of providing services to the public after disasters). SB 1953 applies to all urgent care facilities (including those built prior to the 1973 Hospital Act) and affects approximately 2,500 buildings on 475 campuses statewide.

SB 1953 directed OSHPD, in consultation with the Hospital Building Safety Board, to develop emergency regulations including "...earthquake performance categories with subgradations for risk to life, structural soundness, building contents, and nonstructural systems that are critical to providing basic services to hospital inpatients and the public after a disaster." (Health and Safety Code Section 130005).

In 2001, recognizing the continuing need to assess the adequacy of policies and the application of advances in technical knowledge and understanding, the California Seismic Safety Commission created an Ad Hoc Committee to re-examine the compliance with the Alquist Hospital Seismic Safety Act. The formation of the Committee was prompted by the evaluations of hospital buildings reported to OSHPD that revealed that about 40 percent of California's operating hospitals are in the highest category of collapse risk."

Earthquake Education

Earthquake research and education activities are conducted at several major universities in the southern California region, including Cal Tech, University of Southern California (USC), University of California - Los Angeles (UCLA), University of California – Santa Barbara (UCSB), University of California – Irvine (UCI), and University of California – San Diego (UCSD), and San Diego State University (SDSU).

The local clearinghouse for earthquake information is the Southern California Earthquake Center (SCEC) located at the University of Southern California, Los Angeles, CA 90089. Administrative offices are located on the first floor of the Zumberge Hall of Science on Trousdale Parkway, Telephone: (213) 740-5843, Fax: (213) 740-0011, Email: SCECinfo@usc.edu, Website: <http://www.scec.org>. The Southern California Earthquake Center (SCEC) is a community of scientists and specialists who actively coordinate research on earthquake hazards at fifteen core institutions, and communicate earthquake information to the public. SCEC is a National Science Foundation (NSF) Science and Technology Center and is co-funded by the United States Geological Survey (USGS).

In addition, Los Angeles County, along with 15 other southern California counties, sponsors the Emergency Survival Program (ESP), an educational program for learning how to prepare for earthquakes and other disasters (<http://lacoa.org/esp.htm>). Many school districts have very active emergency preparedness programs that include earthquake drills and periodic disaster response team exercises.

Earthquake Resource Directory

Local and Regional Resources

Southern California Earthquake Center (SCEC)

Level: Regional Hazard: Earthquake www.scec.org
3651 Trousdale Parkway Suite 169
Los Angeles, CA 90089-0742 Ph: 213-740-5843 Fx: 213-740-0011

Notes: The Southern California Earthquake Center (SCEC) gathers new information about earthquakes in southern California, integrates this information into a comprehensive and predictive understanding of earthquake phenomena, and communicates this understanding to end-users and the general public in order to increase earthquake awareness, reduce economic losses, and save lives.

Western States Seismic Policy Council (WSSPC)

Level: Regional Hazard: Earthquake www.wsspc.org
801 K Street Suite 1236
Sacramento, CA 95814 Ph: 916-444-6816 Fx: 916-444-8077

Notes: The WSSPC develops seismic policies and share information to promote programs intended to reduce earthquake-related losses.

Earthquake Country Alliance (ECA)

Level: Regional Hazard: Earthquake www.wsspc.org
3651 Trousdale Parkway Suite 169
Los Angeles, CA 90089 Ph: 213-740-1560

Notes: The Earthquake Country Alliance is a public-private partnership of people, organizations and regional alliances that work together to improve preparedness, mitigation and resiliency.

State Resources

California Department of Transportation (CalTrans)

Level: State Hazard: Multi <http://www.dot.ca.gov/>
3347 Michelson Drive, Suite 100 District 12 Offices
Irvine, CA 92612-0611 Ph: 949-724-2000

Notes: CalTrans is responsible for the design, construction, maintenance, and operation of the California State Highway System, as well as that portion of the Interstate Highway System within the state's boundaries. Alone and in partnership with Amtrak, CalTrans is also involved in the support of intercity passenger rail service in California.

California Resources Agency

Level: State Hazard: Multi <http://resources.ca.gov/>

1416 Ninth Street Suite 1311
Sacramento, CA 95814 Ph: 916-653-5656 Fx: 916-653-8102

Notes: The California Resources Agency restores, protects and manages the state's natural, historical and cultural resources for current and future generations using solutions based on science, collaboration and respect for all the communities and interests involved.

California Geological Survey

Level: State Hazard: Multi www.consrv.ca.gov/cgs/index.htm
801 K Street MS 12-30
Sacramento, CA 95814 Ph: 916-445-1825 Fx: 916-445-5718

Notes: The California Geological Survey develops and disseminates technical information and advice on California's geology, geologic hazards, and mineral resources.

California Geological Survey: Southern California Regional Office

Junipero Serra Building 320 W. 4th Street, Suite 850
Los Angeles, CA 90013 Ph: 213-239-0877 Fx: 213-239-0894

California Department of Conservation

Level: State Hazard: Multi www.consrv.ca.gov
801 K Street, MS-24-01
Sacramento, CA 95814 Ph: 916-322-1080 Fx: 916-445-0732

Notes: The Department of Conservation provides services and information that promote environmental health, economic vitality, informed land-use decisions and sound management of our state's natural resources.

California Seismic Safety Commission

Level: State Hazard: Earthquake www.seismic.ca.gov
1755 Creekside Oaks Drive Suite 100
Sacramento, CA 95833-3637 Ph: 916-263-5506

Notes: The Seismic Safety Commission investigates earthquakes, researches earthquake-related issues and reports, and recommends to the Governor and Legislature, policies and programs needed to reduce earthquake risk. Some of the duties of the Commission include managing California's Earthquake Hazards Reduction Program, reviewing seismic activities funded by the State, providing a consistent policy direction for earthquake-related programs for all agencies at all government levels, proposing and reviewing earthquake-related legislation, conducting public hearings on seismic safety issues, recommending earthquake safety programs to governmental agencies and the private sector, and investigating and evaluating earthquake damage and reconstruction efforts following earthquakes..

Governor's Office of Emergency Services (Cal OES)

Level: State Hazard: Multi www.oes.ca.gov
P.O. Box 419047
Rancho Cordova, CA 95741-9047 Ph: 916-845- 8911 Fx: 916 845- 8910

Notes: The Governor's Office of Emergency Services coordinates overall state agency response to major disasters in support of local government. The office is responsible for assuring the state's readiness to respond to and recover from natural, manmade, and war-caused emergencies, and for assisting local governments in their emergency preparedness, response and recovery efforts.

Federal and National Resources

Building Seismic Safety Council (BSSC)

Level: National Hazard: Earthquake www.bssconline.org
1090 Vermont Ave., NW Suite 700
Washington, DC 20005-4905 Ph: 202-289-7800 Fx: 202-289-1092

Notes: The Building Seismic Safety Council (BSSC) develops and promotes building earthquake risk mitigation regulatory provisions for the nation. Provides a forum that fosters improved seismic safety provisions for the use by the building community in the planning, design, construction, regulation and utilization of buildings.

Federal Emergency Management Agency, Region IX

Level: Federal Hazard: Multi www.fema.gov
1111 Broadway Suite 1200
Oakland, CA 94607-4052 Ph: 510-627-7100 Fx: 510-627-7112

Notes: The Federal Emergency Management Agency is tasked with responding to, planning for, recovering from and mitigating against disasters.

Federal Emergency Management Agency, Mitigation Division

Level: Federal Hazard: Multi <http://www.fema.gov/what-mitigation/federal-insurance-mitigation-administration>

500 C Street, S.W.
Washington, D.C. 20472 Ph: 202-566-1600 Fx:

Notes: The Mitigation Division manages the National Flood Insurance Program and oversees FEMA's mitigation programs. It has a number of programs and activities which provide citizens protection, with flood insurance; prevention, with mitigation measures and partnerships, with communities throughout the country.

United States Geological Survey

Level: Federal Hazard: Multi <http://www.usgs.gov/>
345 Middlefield Road
Menlo Park, CA 94025 Ph: 650-853-8300 Fx:

Notes: The USGS provides scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life.

Insurance Institute for Business and Home Safety

Level: National Hazard: Multi www.disastersafety.org
4775 E. Fowler Avenue
Tampa, FL 33617 Ph: 813-286-3400 Fx: 813-286-9960

The Institute for Business & Home Safety (IBHS) is a nonprofit association that engages in communication, education, engineering and research. The Institute works to reduce deaths, injuries, property damage, economic losses and human suffering caused by natural disasters.

Publications

“Land Use Planning for Earthquake Hazard Mitigation: Handbook for Planners” by Wolfe, Myer R. et. al., (1986) University of Colorado, Institute of Behavioral Science, National Science Foundation.

This handbook provides techniques that planners and others can utilize to help mitigate for seismic hazards. It provides information on the effects of earthquakes, sources on risk assessment, and effects of earthquakes on the built environment. The handbook also gives examples on application and implementation of planning techniques to be used by local communities.

Contact: Natural Hazards Research and Applications Information Center
Address: University of Colorado, 482 UCB, Boulder, CO 80309-0482
Phone: (303) 492-6818
Fax: (303) 492-2151
Website: <http://www.colorado.edu/UCB/Research/IBS/hazards>

“Public Assistance Debris Management Guide”, FEMA (July 2000).

The Debris Management Guide was developed to assist local officials in planning, mobilizing, organizing, and controlling large-scale debris clearance, removal, and disposal operations. Debris management is generally associated with post-disaster recovery. While it should be compliant with local and county emergency operations plans, developing strategies to ensure strong debris management is a way to integrate debris management within mitigation activities. The “Public Assistance Debris Management Guide” is available in hard copy or on the FEMA website.

“A Safer, More Resilient California: The State Plan for Earthquake Research,” California Seismic Safety Commission (2004).

This is a 5-year statewide earthquake research plan that contains identifies research activities, and provides strategies to receive federal funding to implement the plan. For additional information and to review many more publications issued by the CSSC, refer to their website at <http://www.seismic.ca.gov/pub.html>.

“Putting Down Roots in Earthquake Country,” Southern California Earthquake Center, 2011 edition.

An updated version of a classic booklet that discusses the earthquake risk in California and provides homeowners with specific information on how to earthquake-proof their homes and be prepared for an earthquake. The document is available online from www.earthquakecountry.org/roots. A Spanish version of the pamphlet is also available from the same site.

“7 Steps to an Earthquake Resilient Business – A Supplemental Guide to Putting down Roots in Earthquake Country,” Southern California Earthquake Center, 2008.

This booklet provides information helpful to business owners to earthquake-proof their place of business, keeping their employees safe, and prevent work stoppages or business closure. This document is also available from www.earthquakecountry.org/roots/.

Refer to the References section (Appendix I) for a listing of the reports referenced in this section and other resources.