

Section 6: Flooding Hazards in the City of Long Beach

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

The City of Long Beach is adjacent to the Los Angeles River and the San Gabriel River, both of which are susceptible to flooding events. Flooding poses a threat to life and safety, and can cause severe damage to public and private property.

The Los Angeles River originates at the west end of the San Fernando Valley. The channel extends through the heart of Los Angeles County by flowing east to Glendale where it turns and flows south to the Pacific Ocean. The Los Angeles River is part of a network of dams, reservoirs, debris collection basins, and spreading grounds built to minimize flooding in the County. The floodplain starts in the northeast part of the City of Los Angeles at the Arroyo Seco confluence, passes through the Cities of Los Angeles, Bell, Bell Gardens, South Gate, Lynwood, Lakewood, Paramount, Compton, Bellflower, Carson, Gardena and Long Beach to the Pacific Ocean.

Coastal flooding in Long Beach due to ocean-related events remains a possibility. This flooding can be attributed to the following mechanisms:

- 1) Swell runup from intense offshore winter storms in the Pacific.
- 2) Tsunamis from the Aleutian-Alaskan and Peru-Chile Trenches
(see Hazard-Specific Section: Tsunami).
- 3) Runup from wind waves generated by landfalling storms.
- 4) Swell runup from waves generated off Baja California by tropical cyclones.
- 5) Effects of landfalling tropical cyclones.

The southern California coastline is exposed to waves generated by winter and summer storms originating in the Pacific Ocean. It is not uncommon for these storms to cause 15-foot breakers. The occurrence of such a storm event, in combination with high astronomical tides and strong winds can cause a significant wave runup and allow storm waves to attack higher than normal elevations along the coastline. When this occurs, shoreline erosion and coastal flooding frequently results in damage to inadequately protected structures and facilities located along low-lying portions of the shoreline.

Tsunamis are considered highly unlikely due to geographical and geological features of the coastal region. However, on May 22, 1960, seismic-triggered ocean waves caused significant damage in Long Beach harbor (see Hazard-Specific Section: Tsunami).

History of Flooding in the City of Long Beach

The City of Long Beach is susceptible to flooding from two sources: overflow of flood control channels and earthquake-related flood events. Major floods have affected the citizens of the City since as early as the 1800s.

There are a number of rivers in the southern California region, but the river with the best recorded history is the Los Angeles River. The flood history of the Los

Angeles River is generally indicative of the flood history of much of southern California.

Los Angeles County Flood Control District (LACFCD) flood overflow maps for Long Beach indicate a history of flooded streets, sumps, and general flooding along the San Gabriel River, which resulted from the major storms of March, 1938, February 1941, and January 1956. According to the City's MHFP, the City Engineer has indicated that the tropical storm of September 25, 1939 caused extensive coastal flooding. During the storm, 50 homes on the south side of Ocean Boulevard between Granada Avenue and San Gabriel River were seriously damaged or destroyed either by direct wave damage or by erosion of the sand foundations.

On January 20, 1969, the high-intensity rainfall, which coincided with a high tide, prevented an existing storm drain from functioning properly, causing flooding of several residences on Appian Way, in the Belmont Shore area. Commercial buildings in Long Beach were inundated along the Pacific Coast Highway near Pacific Avenue and near the intersection of Orange Avenue and Wardlow Road. Significant erosion damage occurred to the Los Angeles River outlet due to high-velocity flows and floating debris.

On January 5, 1995 flooding occurred in various parts of the City due to heavy rain.

Historic Flooding in Los Angeles County

Records show that since 1811, the Los Angeles River has flooded 30 times, on average once every 6.1 years. But averages are deceiving, for the Los Angeles basin goes through periods of drought and then periods of above average rainfall. Between 1889 and 1891 the river flooded every year, and from 1941 to 1945, the river flooded 5 times. Conversely, from 1896 to 1914, a period of 18 years, and again from 1944 to 1969, a period of 25 years, the river did not have serious floods.¹

Table 6-1: Major Floods of the Los Angeles River

Major Floods of the Los Angeles River	
1811	Flooding
1815	Flooding
1825	L.A. River changed its course back from the Ballona wetlands to San Pedro
1832	Heavy flooding
1861-62	Heavy flooding. Fifty inches of rain falls during December and January.
1867	Floods create a large, temporary lake out to Ballona Creek.
1876	The Novician Deluge

1884	Heavy flooding causes the river to change course again, turning east to Vernon and then southward to San Pedro.
1888-1891	Annual floods
1914	Heavy flooding. Great damage to the harbor.
1921	Flooding
1927	Moderate flood
1934	Moderate flood starting January 1. Forty dead in La Canada.
1938	Great County-wide flood with 4 days of rain. Most rain on day 4.
1941-44	L.A. River floods five times.
1952	Moderate flooding
1969	One heavy flood after 9 day storm. One moderate flood.
1978	Two moderate floods
1979	Los Angeles experiences severe flooding and mudslides.
1980	Flood tops banks of river in Long Beach. Sepulveda Basin spillway almost opened.
1983	Flooding kills six people.
1992	15 year flood. Motorists trapped in Sepulveda basin. Six people dead.
1994	Heavy flooding

Sources: <http://www.lalc.k12.ca.us/target/units/river/tour/hist.html> and
<http://www.losangelesalmanac.com/topics/History/hi01i.htm>

While the City of Long Beach is 20 miles south of downtown Los Angeles, it is not so far away as to not be affected by the heavy rains that brought flooding to Los Angeles. In addition, the towering mountains that give the Los Angeles region its spectacular views also wring a great deal of rain out of the storm clouds that pass through. Because the mountains are so steep, the rainwater moves rapidly down the slopes and across the coastal plains on its way to the ocean.

"The Santa Monica, Santa Susana and Verdugo Mountains, which surround three sides of the valley, seldom reach heights above three thousand feet.

The Western San Gabriel Mountains, in contrast, have elevations of more than seven thousand feet. These higher ridges often trap eastern-moving winter storms. Although downtown Los Angeles averages just fifteen inches of rain a year, some mountain peaks in the San Gabriels receive more than forty inches of precipitation annually²

Naturally, this rainfall moves rapidly down stream, often with severe consequences for anything in its path. In extreme cases, flood-generated debris flows will roar down a canyon at speeds near 40 miles per hour with a wall of mud, debris and water tens of feet high.

In southern California, stories of floods, debris flows, persons buried alive under tons of mud and rock and persons swept away to their death in a river flowing at thirty-five miles an hour are without end.

What Factors Create Flood Risk?

Flooding occurs when climate, geology, and hydrology combine to create conditions where water flows outside of its usual course. In the City of Long Beach, geography and climate combine to create chronic seasonal flooding conditions.

Winter Rainfall

Over the last 125 years, the average annual rainfall in Los Angeles is 14.9 inches. But the term "average" means very little as the annual rainfall during this time period has ranged from only 4.35 inches in 2001-2002 to 38.2 inches in 1883-1884. In fact, in only fifteen of the past 125 years, has the annual rainfall been within plus or minus 10% of the 14.9 inch average. And in only 38 years has the annual rainfall been within plus or minus 20% of the 14.9 inch average. This makes the Los Angeles basin a land of extremes in terms of annual precipitation.

According to the MHFP, the climate of Long Beach, which is to the south of the San Gabriel Mountains, is considered subtropical. Major storms consist of one to several frontal systems which can last up to four or more days. Precipitation is greatly intensified due to the San Gabriel Mountains which lie in the path of storms moving from the west or southwest. The average annual rainfall ranges from 13.8 inches at sea level to 28.2 inches in the San Gabriel Mountains.

Monsoons

Another relatively regular source for heavy rainfall, particularly in the mountains and adjoining cities is from summer tropical storms. Table 6-2 lists tropical storms that have had significant rainfall in the past century, and the general areas affected by these storms. These tropical storms usually coincide with El Niño years.

Table 6-2: Tropical Cyclones of Southern California

Tropical cyclones that have affected Southern California during the 20th Century			
Month-Year	Date(s)	Area(s) Affected	Rainfall
July 1902	20th & 21 st	Deserts & Southern Mountains	up to 2"
Aug. 1906	18th & 19th	Deserts & Southern Mountains	up to 5"
Sept. 1910	15th	Mountains of Santa Barbara County	2"
Aug. 1921	20th & 21st	Deserts & Southern Mountains	up to 2"
Sept. 1921	30th	Deserts	up to 4"
Sept. 1929	18th	Southern Mountains & Deserts	up to 4"
Sept. 1932	28 th - Oct 1st	Mountains & Deserts, 15 Fatalities	up to 7"
Aug. 1935	25th	Southern Valleys, Mountains & Deserts	up to 2"
Sept. 1939	4th - 7th	Southern Mountains, Southern & Eastern Deserts	up to 7"
	11th & 12th	Deserts, Central & Southern Mountains	up to 4"
	19th - 21st	Deserts, Central & Southern Mountains	up to 3"
	25th	Long Beach, W/ Sustained Winds of 50 Mph	5"
Surrounding Mountains		6 to 12"	
Sept. 1945	9th & 10th	Central & Southern Mountains	up to 2"
Sept. 1946	30 th - Oct 1 st	Southern Mountains	up to 4"
Aug. 1951	27th - 29th	Southern Mountains & Deserts	2 to 5"
Sept. 1952	19th - 21st	Central & Southern Mountains	up to 2"
July 1954	17th - 19th	Deserts & Southern Mountains	up to 2"
July 1958	28th & 29th	Deserts & Southern Mountains	up to 2"
Sept. 1960	9th & 10th	Julian	3.40"
Sept. 1963	17th - 19th	Central & Southern Mountains	up to 7"
Sept. 1967	1st - 3rd	Southern Mountains & Deserts	2"
Oct. 1972	6th	Southeast Deserts	up to 2"
Sept. 1976	10th & 11th	Central & Southern Mountains. Ocotillo, CA was Destroyed 3 Fatalities	6 to 12"
Aug. 1977	n/a	Los Angeles	2"
		Mountains	up to 8"
Oct. 1977	6th & 7th	Southern Mountains & Deserts	up to 2"
Sept. 1978	5th & 6th	Mountains	3"

Tropical cyclones that have affected Southern California during the 20th Century			
Sept. 1982	24th - 26th	Mountains	up to 4"
Sept. 1983	20th & 21st	Southern Mountains & Deserts	up to 3"
http://www.fema.gov/nwz97/eln_scal.shtml			

Geography and Geology

The greater Los Angeles Basin is the product of rainstorms and erosion for millennia. "Most of the mountains that ring the valleys and coastal plain are deeply fractured faults and, as they (the mountains) grew taller, their brittle slopes were continually eroded. Rivers and streams carried boulders, rocks, gravel, sand, and silt down these slopes to the valleys and coastal plain....In places these sediments are as much as twenty thousand feet thick"³

Much of the coastal plain rests on the ancient rock debris and sediment washed down from the mountains. This sediment can act as a sponge, absorbing vast quantities of rain in those years when heavy rains follow a dry period. But like a sponge that is near saturation, the same soil fills up rapidly when a heavy rain follows a period of relatively wet weather. So even in some years of heavy rain, flooding is minimal because the ground is relatively dry. The same amount of rain following a wet period of time can cause extensive flooding.

The greater Los Angeles Basin is for all intents and purposes developed. This leaves precious little open land to absorb rainfall. This lack of open ground forces water to remain on the surface and rapidly accumulate. If it were not for the massive flood control system with its concrete lined river and stream beds, flooding would be a much more common occurrence. And the tendency is towards even less and less open land. In-fill building is becoming a much more common practice in many areas. Developers tear down an older home which typically covers up to 40% of the lot size and replacing it with three or four town homes or apartments which may cover 90-95% of the lot.

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

Flood Terminology

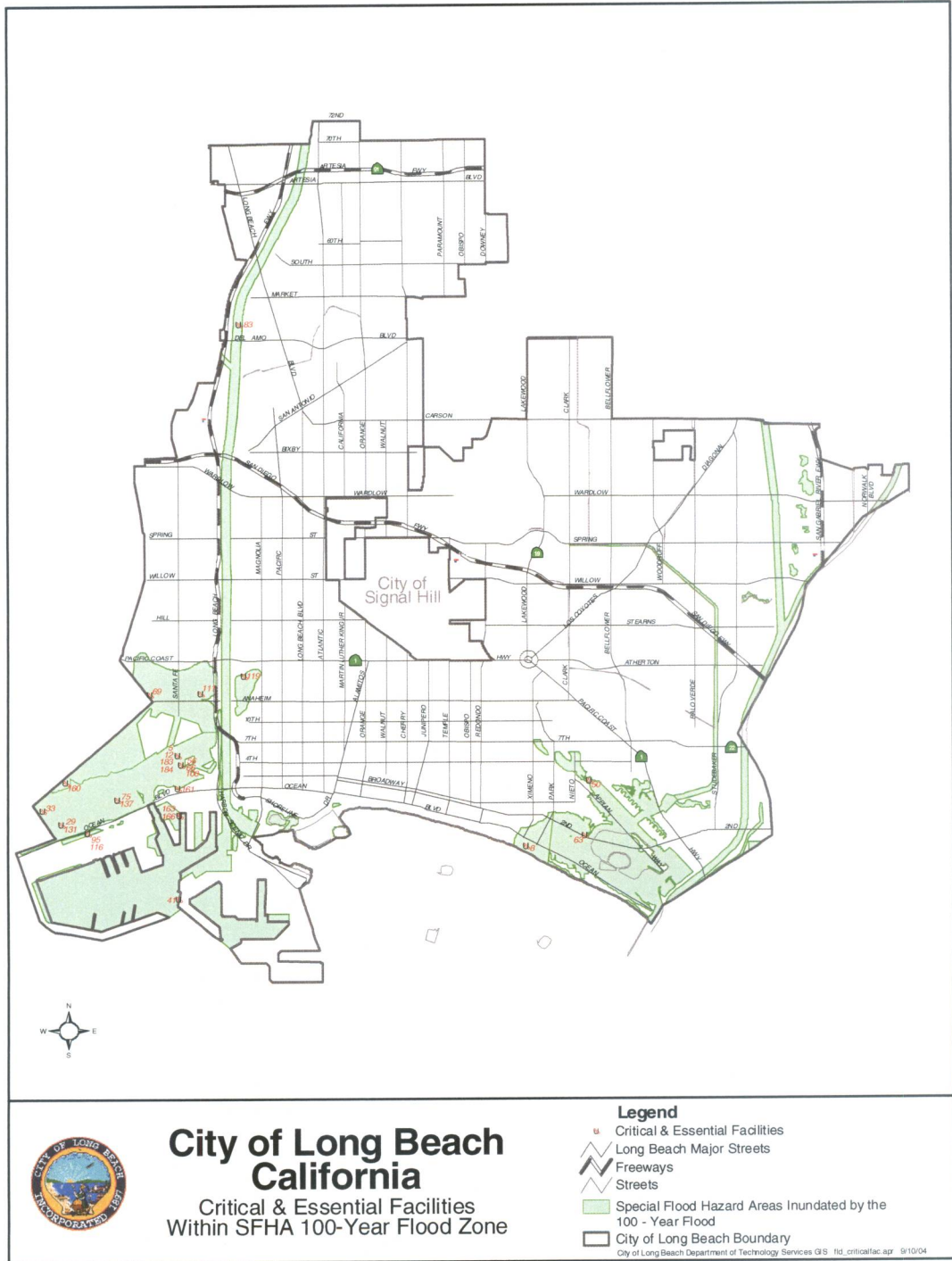
Floodplain

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

100-Year Flood

The 100-year flooding event is the flood having a one percent chance of being equaled or exceeded in magnitude in any given year. Contrary to popular belief, it is not a flood occurring once every 100 years. The 100-year floodplain is the area adjoining a river, stream, or watercourse covered by water in the event of a 100-year flood. Map 6-1 illustrates the 100-year floodplain in the City of Long Beach.

**Map 6-1: 100-Year Floodplains in the City of Long Beach
(Source: City of Long Beach GIS)**



Floodway

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

The City of Long Beach Zoning Ordinance definitions relating to flooding are contained in Chapter 21.62 Flood Damage Prevention. Refer to the Zoning Code for definitions and regulations concerning development in and around the 100-year floodplain.

Characteristics of Flooding

A potential flooding hazard in the City of Long Beach could be caused by two primary sources – rains or earthquakes.

Riverine Flooding

Riverine flooding is the overbank flooding of rivers and streams. The natural processes of riverine flooding add sediment and nutrients to fertile floodplain areas. Flooding in large river systems typically results from large-scale weather systems that generate prolonged rainfall over a wide geographic area, causing flooding in hundreds of smaller streams, which then drain into the major rivers. Map 6-1 shows the various river basins (or flood zones) in the City of Long Beach.

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

Urban Flooding

As land is converted from fields or woodlands to roads and parking lots, it loses its ability to absorb rainfall. Urbanization of a watershed changes the hydrologic systems of the basin. Heavy rainfall collects and flows faster on impervious concrete and asphalt surfaces. The water moves from the clouds, to the ground, and into streams at a much faster rate in urban areas. Adding these elements to the hydrological systems can result in flood waters that rise very rapidly and peak with violent force.

Almost 100% of the area in the City of Long Beach has a high concentration of impermeable surfaces that either collect water, or concentrate the flow of water in unnatural channels. During periods of urban flooding, streets can become swift moving rivers and basements can fill with water. Storm drains often back up with

debris causing additional, localized flooding.

Dam Failure Flooding

Loss of life and damage to structures, roads, and utilities may result from a dam failure. Economic losses can also result from a lowered tax base and lack of utility profits. These effects would certainly accompany the failure of one of the major dams upstream from the City of Long Beach. There are a total of 3 dams upstream of the City of Long Beach holding millions (or billions) of gallons of water. Because dam failure can have severe consequences, FEMA requires that all dam owners develop Emergency Action Plans (EAP) for warning, evacuation, and post-flood actions. Although there may be coordination with county officials in the development of the EAP, the responsibility for developing potential flood inundation maps and facilitation of emergency response is the responsibility of the dam owner. For more detailed information regarding dam failure flooding, and potential flood inundation zones for a particular dam in the county, refer to the individual Dam Emergency Action Plan.

There have been a total of 45 dam failures in California, since the 19th century. The significant dam failures in southern California are listed in Table 6-3.

Table 6-3: Dam Failures in Southern California

Sheffield	Santa Barbara	1925	Earthquake slide
Puddingstone	Pomona	1926	Overtopping during construction
Lake Hemet	Palm Springs	1927	Overtopping
Saint Francis	San Francisquito Canyon	1928	Sudden failure at full capacity through foundation, 426 deaths
Cogswell	Monrovia	1934	Breaching of concrete cover
Baldwin Hills	Los Angeles	1963	Leak through embankment turned into washout, 3 deaths

http://cee.engr.ucdavis.edu/faculty/lund/dams/Dam_History_Page/Failures.htm

The two most significant dam failures are the St. Francis Dam in 1928 and the Baldwin Hills Dam in 1963.

“The failure of the St. Francis Dam, and the resulting loss of over 500 lives in the path of a roaring wall of water, was a scandal that resulted in the almost complete destruction of the reputation of its builder, William Mulholland.

Mulholland was an immigrant from Ireland who rose up through the ranks of the city's water department to the position of chief

engineer. It was he who proposed, designed, and supervised the construction of the Los Angeles Aqueduct, which brought water from the Owens Valley to the city. The St. Francis Dam, built in 1926, was 180 feet high and 600 feet long; it was located near Saugus in the San Francisquito Canyon.

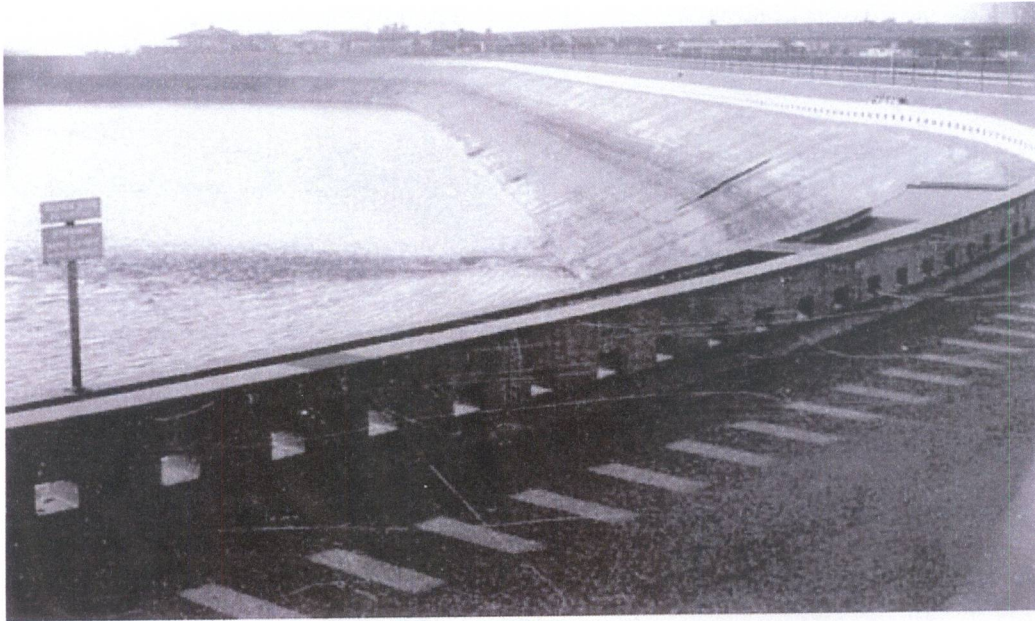
The dam gave way on March 12, 1928, three minutes before midnight. Its waters swept through the Santa Clara Valley toward the Pacific Ocean, about 54 miles away. 65 miles of valley was devastated before the water finally made its way into the ocean between Oxnard and Ventura. At its peak the wall of water was said to be 78 feet high; by the time it hit Santa Paula, 42 miles south of the dam, the water was estimated to be 25 feet deep. Almost everything in its path was destroyed: livestock, structures, railways, bridges, and orchards. By the time it was over, parts of Ventura County lay under 70 feet of mud and debris. Over 500 people were killed and damage estimates topped \$20 million.”⁴

The Baldwin Hills dam failed during the daylight hours, and was one of the first disaster events documented by a live helicopter broadcast.

“The Baldwin Hills Dam collapsed with the fury of a thousand cloudbursts, sending a 50-foot wall of water down Cloverdale Avenue and slamming into homes and cars on Dec. 14, 1963.

Five people were killed. Sixty-five hillside houses were ripped apart, and 210 homes and apartments were damaged. The flood swept northward in a V-shaped path roughly bounded by La Brea Avenue and Jefferson and La Cienega Boulevards.

Photo 6-1: Baldwin Hills Dam



Baldwin Hills Dam - Dark spot in upper right hand quadrant shows the beginning of the break in the dam.

The earthen dam that created a 19-acre reservoir to supply drinking water for West Los Angeles residents ruptured at 3:38 p.m. As a pencil-thin crack widened to a 75-foot gash, 292 million gallons surged out. It took 77 minutes for the lake to empty. But it took a generation for the neighborhood below to recover. And two decades passed before the Baldwin Hills ridge top was reborn.

The cascade caused an unexpected ripple effect that is still being felt in Los Angeles and beyond. It foreshadowed the end of urban-area earthen dams as a major element of the Department of Water and Power's water storage system. It prompted a tightening of Division of Safety of Dams control over reservoirs throughout the state.

The live telecast of the collapse from a KTLA-TV helicopter is considered the precursor to airborne news coverage that is now routine everywhere.”⁵

Debris Flows

Another flood related hazard that can affect certain parts of the southern California region are debris flows. Most typically debris flows occur in mountain canyons and the foothills against the San Gabriel Mountains. However, any hilly or mountainous area with intense rainfall and the proper geologic conditions may experience one of these very sudden and devastating events.

“Debris flows, sometimes referred to as mudslides, mudflows,

lahars, or debris avalanches, are common types of fast-moving landslides. These flows generally occur during periods of intense rainfall or rapid snow melt. They usually start on steep hillsides as shallow landslides that liquefy and accelerate to speeds that are typically about 10 miles per hour, but can exceed 35 miles per hour. The consistency of debris flow ranges from watery mud to thick, rocky mud that can carry large items such as boulders, trees, and cars. Debris flows from many different sources can combine in channels, and their destructive power may be greatly increased. They continue flowing down hills and through channels, growing in volume with the addition of water, sand, mud, boulders, trees, and other materials. When the flows reach flatter ground, the debris spreads over a broad area, sometimes accumulating in thick deposits that can wreak havoc in developed areas.”⁶

Coastal Flooding

Low lying coastal communities of southern California have one other source of flooding, coastal flooding. This occurs most often during storms which bring higher than normal tides. Storms, the time of year and the tidal cycle can sometimes work to bring much higher than normal tides which cause flooding in low lying coastal areas. This hazard however is limited to those areas.

What is the Effect of Development on Floods?

When structures or fill are placed in the floodway or floodplain water is displaced. Development raises the river levels by forcing the river to compensate for the flow space obstructed by the inserted structures and/or fill. When structures or materials are added to the floodway or floodplain and no fill is removed to compensate, serious problems can arise. Flood waters may be forced away from historic floodplain areas. As a result, other existing floodplain areas may experience flood waters that rise above historic levels. Local governments must require engineer certification to ensure that proposed developments will not adversely affect the flood carrying capacity of the Special Flood Hazard Area (SFHA). Displacement of only a few inches of water can mean the difference between no structural damage occurring in a given flood event, and the inundation of many homes, businesses, and other facilities. Careful attention should be given to development that occurs within the floodway to ensure that structures are prepared to withstand base flood events. In highly urbanized areas, increased paving can lead to an increase in volume and velocity of runoff after a rainfall event, exacerbating the potential flood hazards. Care should be taken in the development and implementation of storm water management systems to ensure that these runoff waters are dealt with effectively.

How are Flood-Prone Areas Identified?

Flood maps and Flood Insurance Studies (FIS) are often used to identify flood-prone areas. The NFIP was established in 1968 as a means of providing low-cost flood insurance to the nation's flood-prone communities. The NFIP also

reduces flood losses through regulations that focus on building codes and sound floodplain management. In the City of Long Beach, the NFIP and related building code regulations went into effect on September 15, 1983. NFIP regulations (44 Code of Federal Regulations (CFR) Chapter 1, Section 60, 3) require that all new construction in floodplains must be elevated at or above base flood level.

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

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

FEMA flood maps are not entirely accurate. These studies and maps represent flood risk at the point in time when FEMA revised the studies, and does not incorporate planning for floodplain changes in the future due to new development. Although FEMA is considering changing that policy, it is optional for local communities. The FEMA FIRM map for the City of Long Beach was completed on January 11, 2002.

Nearly all of the areas designated as Zone X, which is in the 500-year flood area, is residential. Zone AE, which is the 100-year flood hazard area, includes the Peninsula, Naples and Belmont Shore east of Park Avenue. Less than 10% of the City's population is in the 100-year flood hazard area (Source: Long Beach Public Works).

Flood Mapping Methods and Techniques

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

Communities find it particularly useful to overlay flood hazard areas on tax assessment parcel maps. This allows a community to evaluate the flood hazard

risk for a specific parcel during review of a development request. Coordination between FEMA and local planning jurisdictions is the key to making a strong connection with GIS technology for the purpose of flood hazard mapping.

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

Hazard Assessment

Hazard Identification

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

Vulnerability Assessment

Vulnerability assessment is the second step of flood-hazard assessment. It combines the floodplain boundary, generated through hazard identification, with an inventory of the property within the floodplain. Understanding the population and property exposed to natural hazards will assist in reducing risk and preventing loss from future events. Because site-specific inventory data and inundation levels given for a particular flood event (10-year, 25-year, 50-year, 100-year, 500-year) are not readily available, calculating a community's vulnerability to flood events is not straightforward. The amount of property in the floodplain, as well as the type and value of structures on those properties, should be calculated to provide a working estimate for potential flood losses.

Disruption of Critical Services

Critical facilities include police stations, fire stations, hospitals, shelters, and other facilities that provide important services to the community. These facilities and their services need to be functional after a flooding event. Vulnerability of these facilities is indicated on Table 4-2 in Section 4, Risk Assessment.

Risk Analysis

Risk analysis is the third and most advanced phase of a hazard assessment. It builds upon the hazard identification and vulnerability assessment. A flood risk analysis for the City of Long Beach should include two components: (1) the life

and value of property that may incur losses from a flood event (defined through the vulnerability assessment); and (2) the number and type of flood events expected to occur over time. Within the broad components of a risk analysis, it is possible to predict the severity of damage from a range of events. Flow velocity models can assist in predicting the amount of damage expected from different magnitudes of flood events. The data used to develop these models is based on hydrological analysis of landscape features. Changes in the landscape, often associated with human development, can alter the flow velocity and the severity of damage that can be expected from a flood event.

Using GIS technology and flow velocity models, it is possible to map the damage that can be expected from flood events over time. It is also possible to pinpoint the effects of certain flood events on individual properties. At the time of publication of this plan, data was insufficient to conduct a risk analysis for flood events in the City of Long Beach. However, the current mapping projects will result in better data that will assist in understanding risk.

Community Flood Issues

What is Susceptible to Damage during a Flood Event?

The largest impact on communities from flood events is the loss of life and property. During certain years, property losses resulting from flood damage are extensive. Development in the floodplains of the City of Long Beach will continue to be at risk from flooding because flood damage occurs on a regular basis throughout the county. Property loss from floods strikes both private and public property.

Property Loss Resulting from Flooding Events

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

Mobilehomes

Statewide, the 1996 floods destroyed 156 housing units. Of those units, 61% were mobilehomes and trailers. Many older mobilehome parks are located in floodplain areas. Mobilehomes have a lower level of structural stability than stick-built homes, and must be anchored to provide additional structural stability during flood events. Because of confusion in the late 1980s resulting from multiple changes in NFIP regulations, there are some communities that do not actively enforce anchoring requirements. Lack of enforcement of mobilehome

construction standards in floodplains can contribute to severe damages from flood events.

According to the 2002 FIRM map, none of the City's mobilehome parks are located in the 100-year flood hazard area.

Business/Industry

Flood events impact businesses by damaging property and by interrupting business. Flood events can cut off customer access to a business as well as close a business for repairs. A quick response to the needs of businesses affected by flood events can help a community maintain economic vitality in the face of flood damage. Responses to business damages can include funding to assist owners in elevating or relocating flood-prone business structures.

Public Infrastructure

Publicly owned facilities are a key component of daily life for all citizens of the county. Damage to public water and sewer systems, transportation networks, flood control facilities, emergency facilities, and offices can hinder the ability of the government to deliver services. Government can take action to reduce risk to public infrastructure from flood events, as well as craft public policy that reduces risk to private property from flood events.

Roads

During natural hazard events, or any type of emergency or disaster, dependable road connections are critical for providing emergency services. Roads systems in the City of Long Beach are maintained by multiple jurisdictions. Federal, state, county, and city governments all have a stake in protecting roads from flood damage. Road networks often traverse floodplain and floodway areas. Transportation agencies responsible for road maintenance are typically aware of roads at risk from flooding.

Stormwater Systems

The following information comes from Section 5.4 Flood Control/Stormwater of March 2004 Technical Background Report for the City's Update to the General Plan)

"The Long Beach Stormwater system outlets to the following regional drains: Los Angeles River, San Gabriel River, Coyote Creek, Los Cerritos Channel, Heather Channel, Los Cerritos Line E, and the Artesia-Norwalk Drain. The City of Long Beach was divided into thirty major drainage basins. Within each major basin there are sub-basins for major drains 36 inches in diameter or larger that have their outfall to a regional drain, regional retention basin or the Harbor. Many major basins contain two or more sub-basins. The sub-basins are further subdivided into drainage areas contributing to a drainage node. There are five storm waste storage basins for Long Beach: Dominguez Basin, Dominguez Gap Basin, California Bowl, Hamilton Bowl, and Colorado Lagoon. There are over 40

stormwater pump stations in Long Beach. Most of the larger capacity stations outfall to the Los Angeles River.”

Water/Wastewater Treatment Facilities

The Long Beach Water Department is responsible for water distribution and waste water treatment.

Water Quality

Environmental quality problems include bacteria, toxins, and pollution.

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**Section 7:
Earth Movement
(Landslides &
Debris Flow)
in the
City of Long Beach**

Why are Landslides a Threat to the City of Long Beach?

Landslides are a serious geologic hazard in almost every state in America. Nationally, landslides cause 25 to 50 deaths each year.¹ The best estimate of direct and indirect costs of landslide damage in the United States range between \$1 and \$2 billion annually.² As a seismically active region, California has had significant number of locations impacted by landslides. Some landslides result in private property damage; other landslides impact transportation corridors, fuel and energy conduits, and communication facilities. They can also pose a serious threat to human life.

Landslides can be broken down into two categories: (1) rapidly moving (generally known as debris flows), and (2) slow moving. Rapidly moving landslides or debris flows present the greatest risk to human life, and people living in or traveling through areas prone to rapidly moving landslides are at increased risk of serious injury. Slow moving landslides can cause significant property damage, but are less likely to result in serious human injuries.

Historic southern California Landslides

1928 St. Francis Dam Failure

Los Angeles County, California. The dam gave way on March 12, and its waters swept through the Santa Clara Valley toward the Pacific Ocean, about 54 miles away. Sixty five miles of valley was devastated, and over 500 people were killed. Damages were estimated at \$672.1 million (year 2000 dollars).³

1956 Portuguese Bend, California

Cost, \$14.6 million (2000 dollars) California Highway 14, Palos Verdes Hills. Land use on the Palos Verdes Peninsula consists mostly of single-family homes built on large lots, many of which have panoramic ocean views. All of the houses were constructed with individual septic systems, generally consisting of septic tanks and seepage pits. Landslides have been active here for thousands of years, but recent landslide activity has been attributed in part to human activity. The Portuguese Bend landslide began its modern movement in August 1956, when displacement was noticed at its northeast margin. Movement gradually extended downslope so that the entire eastern edge of the slide mass was moving within 6 weeks. By the summer of 1957, the entire slide mass was sliding towards the sea.⁴

1958-1971 Pacific Palisades, California

Cost, \$29.1 million (2000 dollars) California Highway 1 and house damaged.⁵

1961 Mulholland Cut, California

Cost, \$41.5 million (2000 dollars) On Interstate 405, 11 miles north of Santa Monica, Los Angeles County.⁶

1963 Baldwin Hills Dam Failure

On December 14, the 650 foot long by 155 foot high earth fill dam gave way and sent 360 million gallons of water in a fifty foot high wall cascading onto the community below, killing five persons, and damaging 50 million (1963 dollars) of dollars in property.

1969 Glendora, California

Cost, \$26.9 million (2000 dollars) Los Angeles County, 175 houses damaged, mainly by debris flows.⁷

1969 Seventh Ave., Los Angeles County, California

Cost, \$14.6 million (2000 dollars) California Highway 60.⁸

1970 Princess Park, California

Cost, \$29.1 million (2000 dollars) California Highway 14, 10 miles north of Newhall, near Saugus, northern Los Angeles County.⁹

1971 Upper and Lower Van Norman Dams, San Fernando, California

Earthquake-induced landslides Cost, \$302.4 million (2000 dollars). Damage due to the February 9, 1971, magnitude 7.5 San Fernando, California, earthquake. The earthquake of February 9 severely damaged the Upper and Lower Van Norman Dams.¹⁰

1971 Juvenile Hall, San Fernando, California

Landslides caused by the February 9, 1971, San Fernando, California, earthquake Cost, \$266.6 million (2000 dollars). In addition to damaging the San Fernando Juvenile Hall, this 1.2 km-long slide damaged trunk lines of the Southern Pacific Railroad, San Fernando Boulevard, Interstate Highway 5, the Sylmar, California, electrical converter station, and several pipelines and canals.¹¹

1977-1980 Monterey Park, Repetto Hills, Los Angeles County, California

Cost, \$14.6 million (2000 dollars) 100 houses damaged in 1980 due to debris flows.¹²

1978 Bluebird Canyon Orange County

California October 2, cost, \$52.7 million (2000 dollars) 60 houses destroyed or damaged. Unusually heavy rains in March of 1978 may have contributed to initiation of the landslide. Although the 1978 slide area was approximately 3.5 acres, it is suspected to be a portion of a larger, ancient landslide.¹³

1979 Big Rock, California, Los Angeles County

Cost, approximately \$1.08 billion (2000 dollars) California Highway 1 rockslide.¹⁴

1980 Southern California Slides

\$1.1 billion in damage (2000 dollars) Heavy winter rainfall in 1979-90 caused

damage in six southern California counties. In 1980, the rainstorm started on February 8. A sequence of 5 days of continuous rain and 7 inches of precipitation had occurred by February 14. Slope failures were beginning to develop by February 15 and then very high-intensity rainfall occurred on February 16. As much as 8 inches of rain fell in a 6 hour period in many locations. Records and personal observations in the field on February 16 and 17 showed that the mountains and slopes literally fell apart on those 2 days.¹⁵

1983 San Clemente, California, Orange County

Cost, \$65 million (2000 dollars), California Highway 1. Litigation at that time involved approximately \$43.7 million (2000 dollars).¹⁶

1983 Big Rock Mesa, California

Cost, \$706 million (2000 dollars) in legal claims condemnation of 13 houses, and 300 more threatened rockslide caused by rainfall¹⁷

1978-1979, 1980 San Diego County, California

Experienced major damage from storms in 1978, 1979, and 1979-80, as did neighboring areas of Los Angeles and Orange County, California. One hundred and twenty landslides were reported to have occurred in San Diego County during these 2 years. Rainfall for the rainy seasons of 78-79 and 79-80 was 14.82 and 15.61 inches (37.6 and 39.6 cm) respectively, compared to a 125-year average (1850-1975) of 9.71 inches (24.7 cm). Significant landslides occurred in the Friars Formation, a unit that was noted as slide-prone in the Seismic Safety Study for the City of San Diego. Of the nine landslides that caused damage in excess of \$1 million, seven occurred in the Friars Formation, and two in the Santiago Formation in the northern part of San Diego County.¹⁸

1994 Northridge, California Earthquake Landslides

As a result of the magnitude 6.7 Northridge, California, earthquake, more than 11,000 landslides occurred over an area of 10,000 km². Most were in the Santa Susana Mountains and in mountains north of the Santa Clara River Valley. Destroyed dozens of homes, blocked roads, and damaged oil-field infrastructure. Caused deaths from Coccidioidomycosis (valley fever) the spore of which was released from the soil and blown toward the coastal populated areas. The spore was released from the soil by the landslide activity.¹⁹

March 1995 Los Angeles and Ventura Counties, Southern California

Above normal rainfall triggered damaging debris flows, deep-seated landslides, and flooding. Several deep-seated landslides were triggered by the storms, the most notable was the La Conchita landslide, which in combination with a local debris flow, destroyed or badly damaged 11 to 12 homes in the small town of La Conchita, about 20 km west of Ventura. There also was widespread debris-flow and flood damage to homes, commercial buildings, and roads and highways in areas along the Malibu coast that had been devastated by wildfire 2 years before.²⁰

Landslide Characteristics

What is a landslide?

"A landslide is defined as, the movement of a mass of rock, debris, or earth down a slope. Landslides are a type of "mass wasting" which denotes any down slope movement of soil and rock under the direct influence of gravity. The term "landslide" encompasses events such as rock falls, topples, slides, spreads, and flows. Landslides can be initiated by rainfall, earthquakes, volcanic activity, changes in groundwater, disturbance and change of a slope by man-made construction activities, or any combination of these factors. Landslides can also occur underwater, causing tidal waves and damage to coastal areas. These landslides are called submarine landslides."²¹

The size of a landslide usually depends on the geology and the initial cause of the landslide. Landslides vary greatly in their volume of rock and soil, the length, width, and depth of the area affected, frequency of occurrence, and speed of movement. Some characteristics that determine the type of landslide are slope of the hillside, moisture content, and the nature of the underlying materials. Landslides are given different names, depending on the type of failure and their composition and characteristics.

Slides move in contact with the underlying surface. These movements include rotational slides where sliding material moves along a curved surface, and translational slides where movement occurs along a flat surface. These slides are generally slow moving and can be deep. Slumps are small rotational slides that are generally shallow. Slow-moving landslides can occur on relatively gentle slopes and can cause significant property damage, but are far less likely to result in serious injuries than rapidly moving landslides.²²

"Failure of a slope occurs when the force that is pulling the slope downward (gravity) exceeds the strength of the earth materials that compose the slope. They can move slowly, (millimeters per year) or can move quickly and disastrously, as is the case with debris-flows. Debris-flows can travel down a hillside of speeds up to 200 miles per hour (more commonly, 30 – 50 miles per hour), depending on the slope angle, water content, and type of earth and debris in the flow. These flows are initiated by heavy, usually sustained, periods of rainfall, but sometimes can happen as a result of short bursts of concentrated rainfall in susceptible areas. Burned areas charred by wildfires are particularly susceptible to debris flows, given certain soil characteristics and slope conditions."²³

What is a Debris Flow?

A debris or mud flow is a river of rock, earth and other materials, including vegetation that is saturated with water. This high percentage of water gives the debris flow a very rapid rate of movement down a slope. Debris flows often with speeds greater than 20 mile per hour, and can often move much faster.²⁴ This

high rate of speed makes debris flows extremely dangerous to people and property in its path.

Landslide Events and Impacts

Landslides are a common hazard in California. Weathering and the decomposition of geologic materials produces conditions conducive to landslides and human activity further exacerbates many landslide problems. Many landslides are difficult to mitigate, particularly in areas of large historic movement with weak underlying geologic materials. As communities continue to modify the terrain and influence natural processes, it is important to be aware of the physical properties of the underlying soils as they, along with climate, create landslide hazards. Even with proper planning, landslides will continue to threaten the safety of people, property, and infrastructure, but without proper planning, landslide hazards will be even more common and more destructive.

The increasing scarcity of build-able land, particularly in urban areas, increases the tendency to build on geologically marginal land. Additionally, hillside housing developments in southern California are prized for the view lots that they provide.

Rock falls occur when blocks of material come loose on steep slopes. Weathering, erosion, or excavations, such as those along highways, can cause falls where the road has been cut through bedrock. They are fast moving with the materials free falling or bouncing down the slope. In falls, material is detached from a steep slope or cliff. The volume of material involved is generally small, but large boulders or blocks of rock can cause significant damage.

Earth flows are plastic or liquid movements in which land mass (e.g. soil and rock) breaks up and flows during movement. Earthquakes often trigger flows.²⁵ Debris flows normally occur when a landslide moves downslope as a semi-fluid mass scouring, or partially scouring soils from the slope along its path. Flows are typically rapidly moving and also tend to increase in volume as they scour out the channel.²⁶ Flows often occur during heavy rainfall, can occur on gentle slopes, and can move rapidly for large distances.

Landslide Conditions

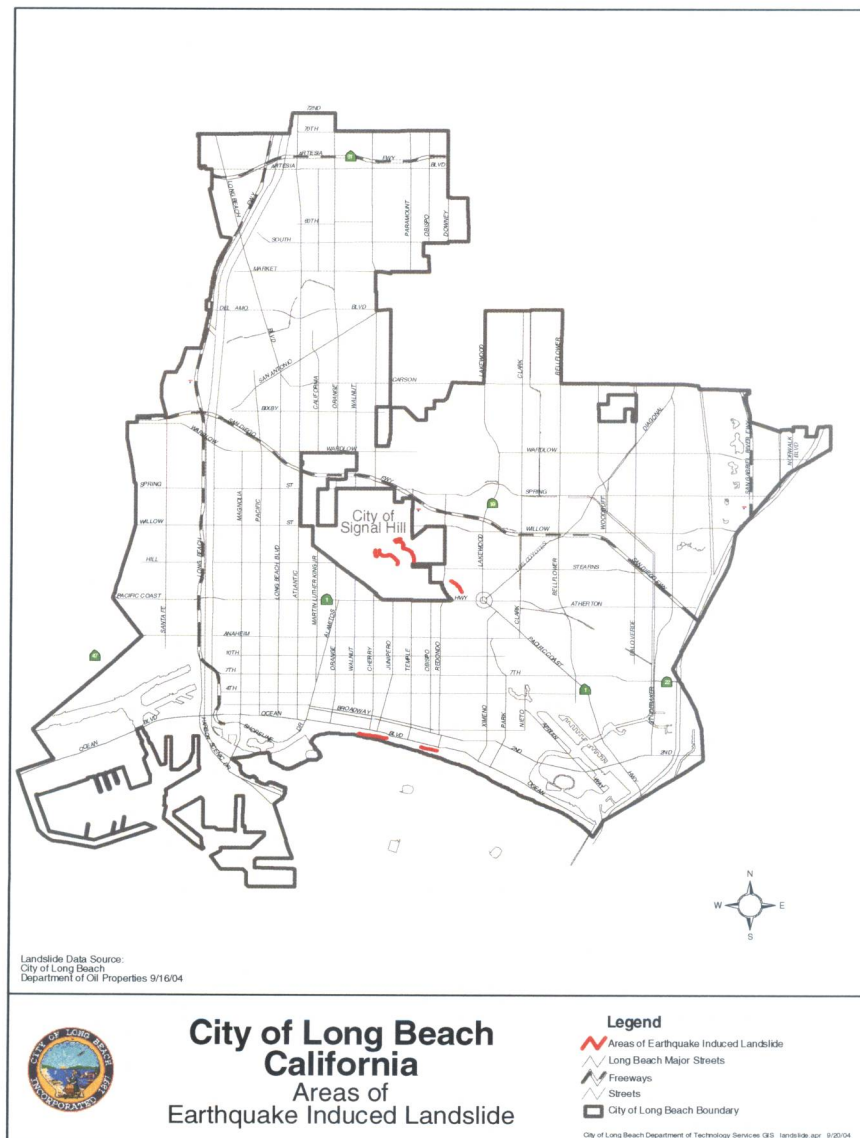
Landslides are often triggered by periods of heavy rainfall. Earthquakes, subterranean water flow and excavations may also trigger landslides. Certain geologic formations are more susceptible to landslides than others. Human activities, including locating development near steep slopes, can increase susceptibility to landslide events. Landslides on steep slopes are more dangerous because movements can be rapid.

Although landslides are a natural geologic process, the incidence of landslides and their impacts on people can be exacerbated by human activities. Grading for road construction and development can increase slope steepness. Grading and construction can decrease the stability of a hill slope by adding weight to the top

of the slope, removing support at the base of the slope, and increasing water content. Other human activities effecting landslides include: excavation, drainage and groundwater alterations, and changes in vegetation.²⁷

Wildland fires in hills covered with chaparral are often a precursor to debris flows in burned out canyons. The extreme heat of a wildfire can create a soil condition in which the earth becomes impervious to water by creating a waxy-like layer just below the ground surface. Since the water cannot be absorbed into the soil, it rapidly accumulates on slopes, often gathering loose particles of soil in to a sheet of mud and debris. Debris flows can often originate miles away from unsuspecting persons, and approach them at a high rate of speed with little warning.

**Map 7-1: Earthquake Induced Landslide Areas
(Source: City of Long Beach GIS)**



Natural Conditions

Natural processes can cause landslides or re-activate historical landslide sites. The removal or undercutting of shoreline-supporting material along bodies of water by currents and waves produces countless small slides each year. Seismic tremors can trigger landslides on slopes historically known to have landslide movement. Earthquakes can also cause additional failure (lateral spreading) that can occur on gentle slopes above steep streams and riverbanks.

Particularly Hazardous Landslide Areas

Locations at risk from landslides or debris flows include areas with one or more of the following conditions:

1. On or close to steep hills;
2. Steep road-cuts or excavations;
3. Existing landslides or places of known historic landslides (such sites often have tilted power lines, trees tilted in various directions, cracks in the ground, and irregular-surfaced ground);
4. Steep areas where surface runoff is channeled, such as below culverts, V-shaped valleys, canyon bottoms, and steep stream channels; and
5. Fan-shaped areas of sediment and boulder accumulation at the outlets of canyons.
6. Canyon areas below hillside and mountains that have recently (within 1-6 years) been subjected to a wildland fire.

Impacts of Development

Although landslides are a natural occurrence, human impacts can substantially affect the potential for landslide failures in the City of Long Beach. Proper planning and geotechnical engineering can be exercised to reduce the threat of safety of people, property, and infrastructure.

Excavation and Grading

Slope excavation is common in the development of home sites or roads on sloping terrain. Grading these slopes can result in some slopes that are steeper than the pre-existing natural slopes. Since slope steepness is a major factor in landslides, these steeper slopes can be at an increased risk for landslides. The added weight of fill placed on slopes can also result in an increased landslide hazard. Small landslides can be fairly common along roads, in either the road cut or the road fill. Landslides occurring below new construction sites are indicators of the potential impacts stemming from excavation.

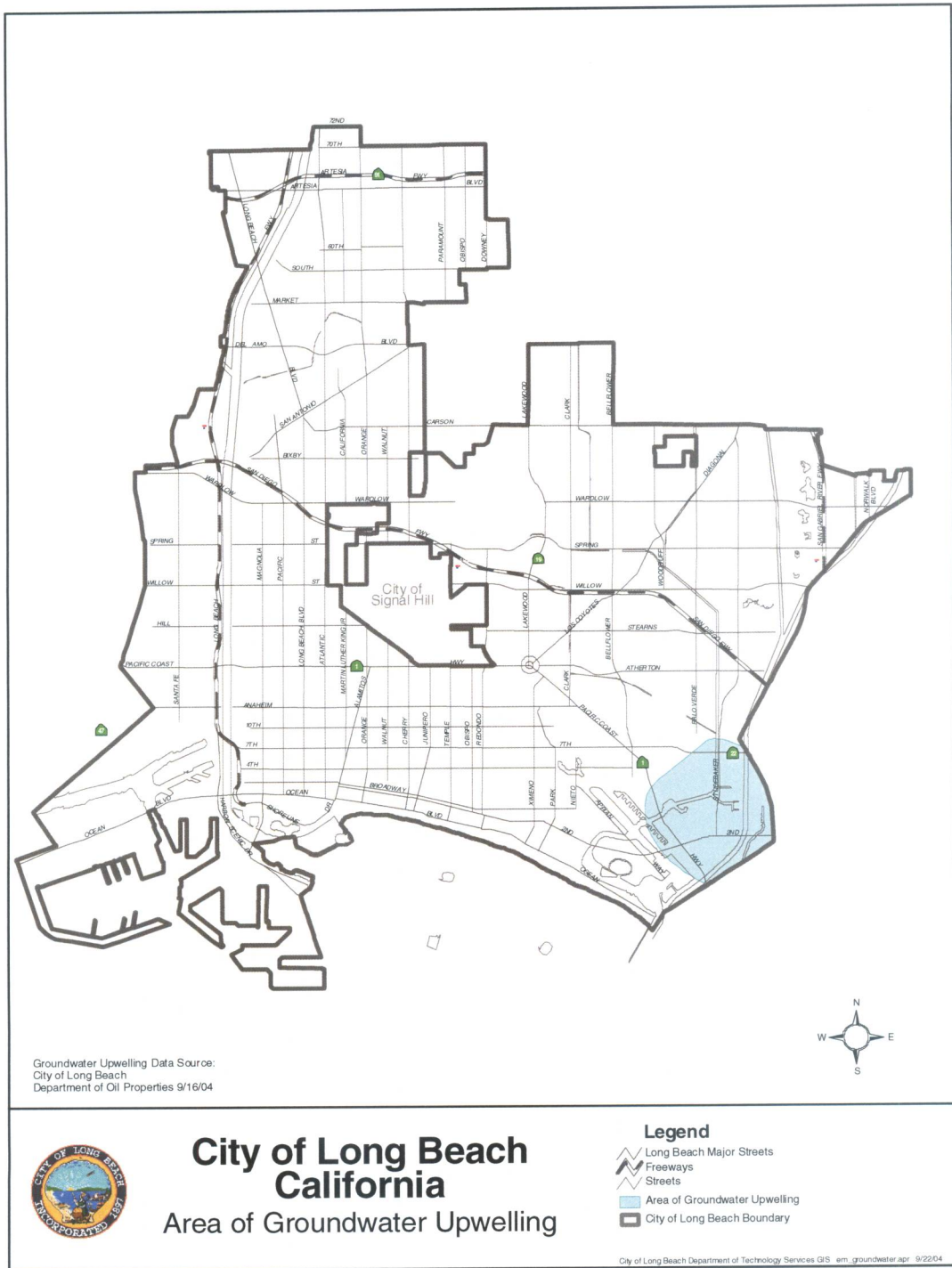
Drainage and Groundwater Alterations

Water flowing through or above ground is often the trigger for landslides. Any activity that increases the amount of water flowing into landslide-prone slopes can increase landslide hazards. Broken or leaking water or sewer lines can be especially problematic, as can water retention facilities that direct water onto slopes. However, even lawn irrigation in landslide prone locations can result in

damaging landslides. Ineffective storm water management and excess runoff can also cause erosion and increase the risk of landslide hazards. Drainage can be affected naturally by the geology and topography of an area; Development that results in an increase in impervious surface impairs the ability of the land to absorb water and may redirect water to other areas. Channels, streams, ponding, and erosion on slopes all indicate potential slope problems.

Road and driveway drains, gutters, downspouts, and other constructed drainage facilities can concentrate and accelerate flow. Ground saturation and concentrated velocity flow are major causes of slope problems and may trigger landslides.²⁸

**Map 7-2: Area of Groundwater Upwelling
(Source: City of Long Beach GIS)**



Changes in Vegetation

Removing vegetation from very steep slopes can increase landslide hazards. Areas that experience wildfire and land clearing for development may have long periods of increased landslide hazard. Also, certain types of ground cover have a much greater need for constant watering to remain green. Changing away from native ground cover plants may increase the risk of landslide.

Earth Movement Hazard Assessment

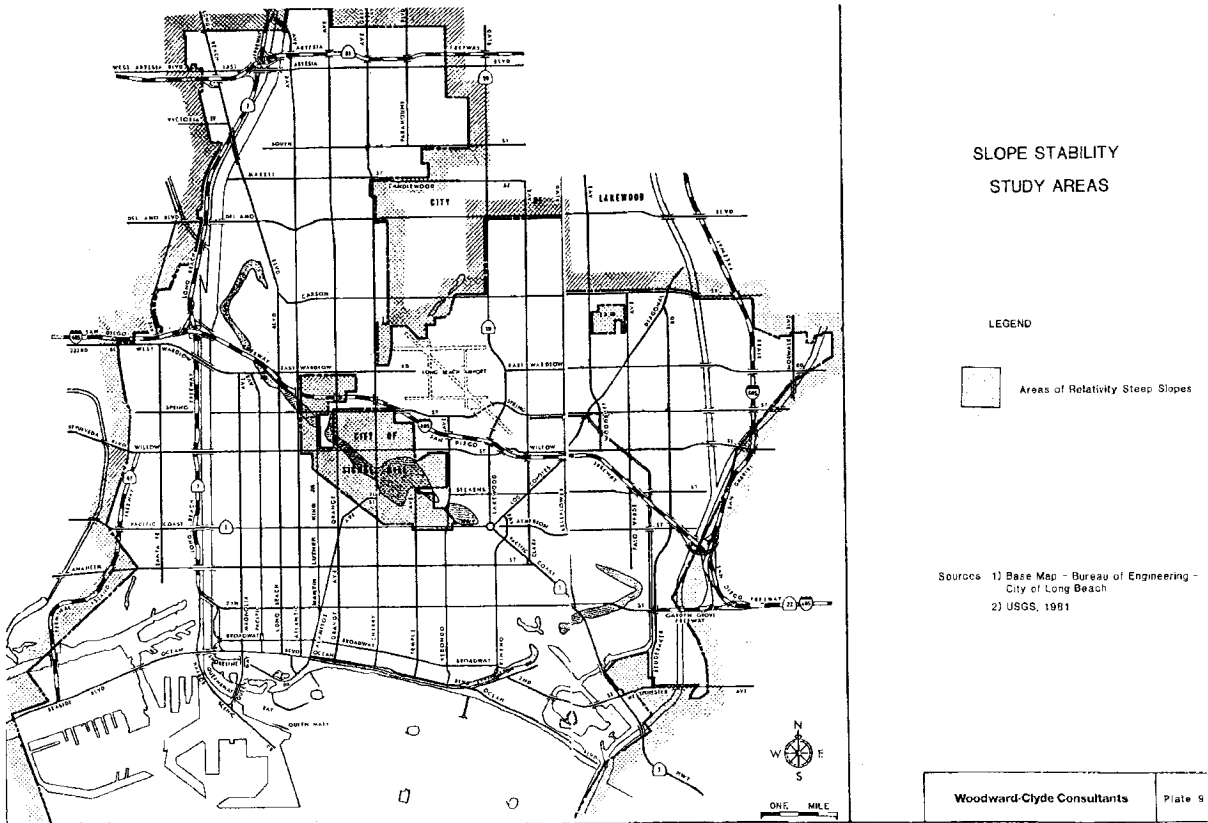
Hazard Identification

Identifying hazardous locations is an essential step towards implementing more informed mitigation activities.

According to the City's General Plan Public Safety Element, mudslides and landslides can be generally categorized under the heading of slope instability. State-wide, such slope instability is a major threat, estimated to cause nearly 10 billion dollars worth of damage between 1970 and the year 2000. The areas most susceptible to this condition are those where: a) slopes are steep, b) soils or soil lenses are weak, cohesionless, or not cemented, c) bedding dips out of the slope, and d) groundwater is present. In Long Beach, slope instability is not a major problem as slopes generally are neither high nor steep. While slope instability is not a major consideration in overall land planning, it is a factor in designing individual sites. Chapter 33 of the California Building Code addresses grading on sites where safety hazards may be created. As Chapter 33 has been adopted and is enforced in the City, slope instability is not a significant or imminent threat to public safety.

The City's 1989 Seismic Safety Element states that the slopes within the City are not high (slopes greater than 50 feet) or steep (generally sloping flatter than 1-1/2:1, horizontal to vertical), and that slope instability has not been a significant problem in the past. The Seismic Safety Element also states that there were only minor slope failures noted during the 1933 Long Beach Earthquake. The Element goes on to state that "the potential for seismically induced slope instability that is not associated with liquefaction or dikes should not be considered as a major consideration in land planning concepts. However, certain areas have been identified where slope stability should be considered for the development of individual sites." The Section 7.4 of the Element recommends soil stabilization measures for those situations.

**Map 7-3: Slope Stability Study Areas
(Source: The City's General Plan Seismic Safety Element)**



Vulnerability and Risk

Vulnerability assessment for landslides will assist in predicting how different types of property and population groups will be affected by a hazard.²⁹ Data that includes specific landslide-prone and debris flow locations in the city can be used to assess the population and total value of property at risk from future landslide occurrences.

At this time, the City of Long Beach Zoning Ordinance does not identify any specific standards for steep slope development.

While a quantitative vulnerability assessment (an assessment that describes number of lives or amount of property exposed to the hazard) has not yet been conducted for the City of Long Beach landslide events, there are many qualitative factors that point to potential vulnerability. Landslides can impact major transportation arteries, blocking residents from essential services and businesses.

Factors included in assessing landslide risk include population and property distribution in the hazard area, the frequency of landslide or debris flow

occurrences, slope steepness, soil characteristics, and precipitation intensity. This type of analysis could generate estimates of the damages to the city due to a specific landslide or debris flow event. At the time of publication of this plan, data was insufficient to conduct a risk analysis and the software needed to conduct this type of analysis was not available.

Community Landslide Issues

What is Susceptible to Earth Movement?

Earth movement can affect utility services, transportation systems, and critical lifelines. Communities may suffer immediate damages and loss of service. Disruption of infrastructure, roads, and critical facilities may also have a long-term effect on the economy. Utilities, including potable water, wastewater, telecommunications, natural gas, and electric power are all essential to service community needs. Loss of electricity has the most widespread impact on other utilities and on the whole community. Natural gas pipes may also be at risk of breakage from earth movements as small as an inch or two.

Roads and Bridges

Losses incurred from earth movement hazards in the City of Long Beach have been associated with the roads. The City contracts with the Los Angeles County Public Works Department for responding to slides that inhibit the flow of traffic or are damaging a road or a bridge. The roads department does its best to communicate with residents impacted by landslides, but can usually only repair the road itself, as well as the areas adjacent to the slide where the city has the right of way.

It is not cost effective to mitigate all slides because of limited funds and the fact that some historical slides are likely to become active again even with mitigation measures. The City's Public Works Department alleviates problem areas by grading slides, and by installing new drainage systems on the slopes to divert water from the landslides. This type of response activity is often the most cost-effective in the short-term, but is only temporary. Unfortunately, many property owners are unaware of slides and the dangers associated with them.

Lifelines and Critical Facilities

Lifelines and critical facilities should remain accessible, if possible, during a natural hazard event. The impact of closed transportation arteries may be increased if the closed road or bridge is critical for hospitals and other emergency facilities. Therefore, inspection and repair of critical transportation facilities and routes is essential and should receive high priority. Losses of power and phone service are also potential consequences of landslide events. Due to heavy rains, soil erosion in hillside areas can be accelerated, resulting in loss of soil support beneath high voltage transmission towers in hillsides and remote areas. Flood events can also cause landslides, which can have serious impacts on gas lines that are located in vulnerable soils.

Community Issues Summary

Earth movement continues to be a potential problem in the City of Long Beach.

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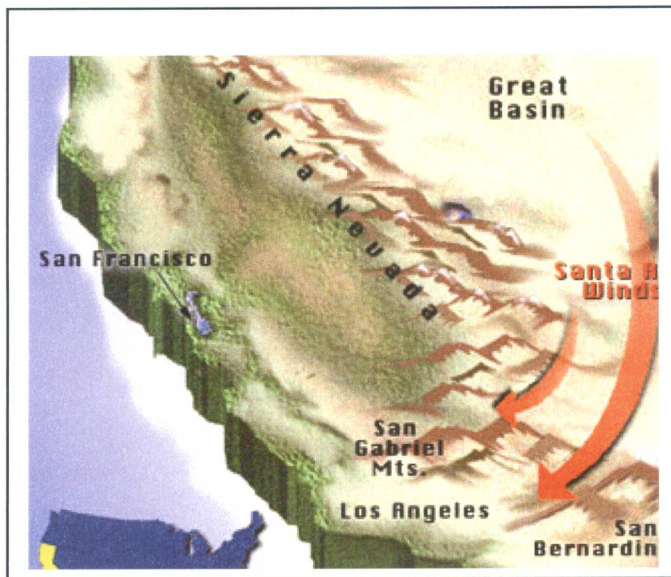
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Section 8: Windstorm Hazards in the City of Long Beach

Why are Severe Windstorms a Threat to the City of Long Beach?

Severe wind storms pose a significant risk to life and property in the region by creating conditions that disrupt essential systems such as public utilities, telecommunications, and transportation routes. High winds can and do occasionally cause tornado-like damage to local homes and businesses. High winds can have destructive impacts, especially to trees, power lines, and utility services.

Figure 8-1: Santa Ana Winds (Source: NASA's "Observatorium")



Two wind patterns occurring over south coastal California, the Catalina Eddy and the Santa Ana Winds, are locally famous effects of a special combination of terrain and atmospheric pressure gradients. Phenomena similar to these occur in a few other areas of the world, but nowhere do they affect such a large number of people and almost nowhere else do they so impact local climatic conditions.

Santa Ana Winds and Tornado-Like Wind Activity

Based on local history, most incidents of high wind in the City of Long Beach are the result of the Santa Ana wind conditions. While high impact wind incidents are not frequent in the area, significant Santa Ana Wind events and sporadic tornado activity have been known to negatively impact the local community.

Windstorm Characteristics

What are Santa Ana Winds?

"Santa Ana winds are generally defined as warm, dry winds that blow from the east or northeast (offshore). These winds occur below the passes and canyons

of the coastal ranges of southern California and in the Los Angeles basin. Santa Ana winds often blow with exceptional speed in the Santa Ana Canyon (the canyon from which it derives its name). Forecasters at the National Weather Service offices in Oxnard and San Diego usually place speed minimums on these winds and reserve the use of "Santa Ana" for winds greater than 25 knots."¹ These winds accelerate to speeds of 35 knots as they move through canyons and passes, with gusts to 50 or even 60 knots.

"The complex topography of southern California combined with various atmospheric conditions create numerous scenarios that may cause widespread or isolated Santa Ana events. Commonly, Santa Ana winds develop when a region of high pressure builds over the Great Basin (the high plateau east of the Sierra Mountains and west of the Rocky Mountains including most of Nevada and Utah). Clockwise circulation around the center of this high pressure area forces air downslope from the high plateau. The air warms as it descends toward the California coast at the rate of 5 degrees F per 1000 feet due to compressional heating. Thus, compressional heating provides the primary source of warming. The air is dry since it originated in the desert, and it dries out even more as it is heated."²

These regional winds typically occur from October to March, and, according to most accounts are named either for the Santa Ana River Valley where they originate or for the Santa Ana Canyon, southeast of Los Angeles, where they pick up speed.

What are Tornadoes?

Tornadoes are spawned when there is warm, moist air near the ground, cool air aloft, and winds that speed up and change direction. An obstruction, such as a house, in the path of the wind causes it to change direction. This change increases pressure on parts of the house, and the combination of increased pressures and fluctuating wind speeds creates stresses that frequently cause structural failures.

In order to measure the intensity and wind strength of a tornado, Dr. T. Theodore Fujita developed the Fujita Tornado Damage Scale. This scale compares the estimated wind velocity with the corresponding amount of suspected damage. The scale measures six classifications of tornadoes with increasing magnitude from an "F0" tornado to a "F6+" tornado.

Table 8-1: Fujita Tornado Damage Scale

Scale	Wind Estimate (mph)	Typical Damage
F0	< 73	Light damage. Some damage to chimneys and TV antennas; breaks twigs off trees; pushes over shallow-rooted trees.
F1	73-112	Moderate damage. Peels surface off roofs; windows broken; light trailer houses pushed or overturned; some trees uprooted or snapped; moving automobiles pushed off the road. 74 mph is the beginning of hurricane wind speed.
F2	113-157	Considerable damage. Roofs torn off frame houses leaving strong upright walls; weak buildings in rural areas demolished; trailer houses destroyed; large trees snapped or uprooted; railroad boxcars pushed over; light object missiles generated; cars blown off highway.
F3	158-206	Severe damage. Roofs and some walls torn off frame houses; some rural buildings completely demolished; trains overturned; steel-framed hangar-warehouse-type structures torn; cars lifted off the ground; most trees in a forest uprooted snapped, or leveled.
F4	207-260	Devastating damage. Whole frame houses leveled, leaving piles of debris; steel structures badly damaged; trees debarked by small flying debris; cars and trains thrown some distances or rolled considerable distances; large missiles generated.
F5	261-318	Incredible damage. Whole frame houses tossed off foundations; steel-reinforced concrete structures badly damaged; automobile-sized missiles generated; trees debarked; incredible phenomena can occur.
F6-F12	319 to sonic	Inconceivable damage. Should a tornado with the maximum wind speed in excess of F5 occur, the extent and types of damage may not be conceived. A number of missiles such as iceboxes, water heaters, storage tanks, automobiles, etc. will create serious secondary damage on structures.

Source: <http://weather.latimes.com/tornadoFAQ.asp>

Microbursts

Like tornados, microbursts, are strong, damaging winds which strike the ground and often give the impression a tornado has struck. They frequently occur during intense thunderstorms. The origin of a microburst is downward moving air from a thunderstorm's core. But unlike a tornado, they affect only a rather small area.

University of Chicago storm researcher Dr Ted Fujita first coined the term "downburst" to describe strong, downdraft winds flowing out of a thunderstorm cell that he believed were responsible for the crash of Eastern Airlines Flight 66 in June of 1975.³

A downburst is a straight-direction surface wind in excess of 39 mph caused by a small-scale, strong downdraft from the base of convective thundershowers and thunderstorms. In later investigations into the phenomena he defined two sub-categories of downbursts: the larger macrobursts and small microbursts.⁴

Macrobursts are downbursts with winds up to 117 mph which spread across a path greater than 2.5 miles wide at the surface and which last from 5 to 30 minutes. The microburst, on the other hand is confined to an even smaller area, less than 2.5 miles in diameter from the initial point of downdraft impact. An intense microburst can result in damaging winds near 270 km/hr (170 mph) and often last for less than five minutes.⁵

“Downbursts of all sizes descend from the upper regions of severe thunderstorms when the air accelerates downward through either exceptionally strong evaporative cooling or by very heavy rain which drags dry air down with it. When the rapidly descending air strikes the ground, it spreads outward in all directions, like a fast-running faucet stream hitting the sink bottom.

When the microburst wind hits an object on the ground such as a house, garage or tree, it can flatten the buildings and strip limbs and branches from the tree. After striking the ground, the powerful outward running gust can wreak further havoc along its path. Damage associated with a microburst is often mistaken for the work of a tornado, particularly directly under the microburst. However, damage patterns away from the impact area are characteristic of straight-line winds rather than the twisted pattern of tornado damage.”⁶

Tornados, like those that occur every year in the Midwest and Southeast parts of the United States, are a rare phenomenon in most of California, with most tornado-like activity coming from micro-bursts.

Local History of Windstorm Events

While the effects of Santa Ana Winds are often overlooked, it should be noted that in 2003, two deaths in southern California were directly related to the fierce condition. A falling tree struck one woman in San Diego.⁷ The second death occurred when a passenger in a vehicle was hit by a flying pickup truck cover launched by the Santa Ana Winds.⁸

Table 8-2: Santa Ana Wind Events in 2003

The following Santa Ana wind events were featured in news resources during 2003:

January 6, 2003 OC Register	"One of the strongest Santa Ana windstorms in a decade toppled 26 power poles in Orange early today, blew over a mobile derrick in Placentia, crushing two vehicles, and delayed Metrolink rail service." This windstorm also knocked out power to thousands of people in northeastern Orange County.
January 8, 2003 CBSNEWS.com	"Santa Ana's roared into Southern California late Sunday, blowing over trees, trucks and power poles. Thousands of people lost power."
March 16, 2003 dailybulletin.com	Fire Officials Brace for Santa Ana Winds - - "The forest is now so dry and so many trees have died that fires, during relatively calm conditions, are running as fast and as far as they might during Santa Ana Winds. Now the Santa Ana season is here. Combine the literally tinder dry conditions with humidity in the single digits and 60-80 mph winds, and fire officials shudder."

Table 8-3: Major Windstorms in the Vicinity of the City of Long Beach

Date	Location and Damage
November 5-6, 1961	Santa Ana winds. Fire in Topanga Canyon
February 10-11, 1973	Strong storm winds: 57 mph at Riverside, 46 Newport Beach. Some 200 trees uprooted in Pacific Beach alone
October 26-27, 1993	Santa Ana winds. Fire in Laguna Hills
October 14, 1997	Santa Ana winds: gusts 87 mph in central Orange County. Large fire in Orange County
December 29, 1997	Gusts 60+ mph at Santa Ana
March 28-29, 1998	Strong storm winds in Orange County: sustained 30-40 mph. Gust 70 mph at Newport Beach, gust 60 Huntington Beach. Trees down, power out, and damage across Orange and San Diego Counties. 1 illegal immigrant dead in Jamul.
September 2, 1998	Strong winds from thunderstorms in Orange County with gusts to 40mph. Large fires in Orange County
December 6, 1998	Thunderstorm in Los Alamitos and Garden Grove: gust 50-60 mph called "almost a tornado"
December 21-22, 1999	Santa Ana winds: gust 68 mph at Campo, 53 Huntington Beach, 44 Orange. House and tree damage in Hemet.
March 5-6, 2000	Strong thunderstorm winds at the coast: gust 60 mph at Huntington Beach Property damage and trees downed along the coast
April 1, 2000	Santa Ana winds: gust 93 mph at Mission Viejo, 67 Anaheim Hills
December 25-26, 2000	Santa Ana winds: gust 87 mph at Fremont Canyon. Damage and injuries in Mira Loma, Orange and Riverside Counties
February 13, 2001	Thunderstorm gust to 89 mph in east Orange

Source:<http://www.wrh.noaa.gov/sandiego/research/Guide/weatherhistory.pdf>

The following is a glimpse of major tornado-like events to hit the City of Long Beach or surrounding areas:

Table 8-4: Major Tornado-like Events in the Vicinity of the City of Long Beach

Major Tornado-like Events in the Orange County Area 1958-2001	
Date	Location and Damage
April 1, 1958	Tornado: Laguna Beach
February 19, 1962	Tornado: Irvine
April 8, 1965	Tornado: Costa Mesa
November 7, 1966	Newport Beach and Costa Mesa: Property Damage
March 16, 1977	Tornado skipped from Fullerton to Brea Damage to 80 homes and injured four people
February 9, 1978	Tornado: Irvine. Property damage and 6 injured
January 31, 1979	Tornado Santa Ana Numerous power outages
November 9, 1982	Tornadoes in Garden Grove and Mission Viejo. Property damage
January 13, 1984	Tornado: Huntington Beach. Property damage
March 16, 1986	Tornado: Anaheim. Property damage
February 22-24, 1987	Tornadoes and waterspouts: Huntington Beach
January 18, 1988	Tornadoes: Mission Viejo and San Clemente. Property damage
February 28, 1991	Tornado: Tustin
March 27, 1991	Tornado: Huntington Beach
December 7, 1992	Tornadoes: Anaheim and Westminster Property damage
January 18, 1993	Tornado: Orange County Property damage
February 8, 1993	Tornado: Brea. Property damage
February 7, 1994	Tornado from Newport Beach to Tustin. Roof and window damage. Trees were also knocked down
December 13, 1994	Two waterspouts about 0.5 mile off Newport Beach
December 13, 1995	Funnel cloud near Fullerton Airport
March 13, 1996	Funnel cloud in Irvine
November 10-11, 1997	Waterspout came ashore at Newport Pier on the 10 th and dissipated over western Costa Mesa. Tornadoes in Irvine on the 11 th and a funnel cloud developed. 10 th : Winds estimated at 60-70 mph. 11 th : Minor power outages occurred with little property damage. A fisherman was blown from one end of Newport Pier to the other. Property and vehicle damage in Irvine from flying debris. Ten cars were thrown a few feet.
December 21, 1997	Waterspout and tornado in Huntington Beach. Damage to boats, houses, and city property
February 24, 1998	Tornado in Huntington Beach. Property damage with a power outage, roof flew ¼ mile

March 13-14, 1998	Numerous waterspouts between Long Beach, Huntington Beach, and Catalina
March 31-April 1, 1998	Numerous funnel clouds reported off Orange County coastline, two of which became waterspouts off Orange County. One waterspout briefly hit the coast off the Huntington Beach pier.
June 6, 1998	Two funnel clouds off Dana Point
December 31, 1998	Funnel clouds in Santa Ana. Waterspout off Costa Mesa coast
February 21, 2000	Tornado: Anaheim Hills. Property damage
October 28, 2000	Funnel clouds around Newport Beach and Costa Mesa
January 10, 2001	Funnel cloud at Orange County airport and Newport Beach
February 24, 2001	Tornado in Orange. Damage to warehouse, 6 structures, fences, and telephone wires.
Source: http://www.wrh.noaa.gov/sandiego/research/Guide/weatherhistory.pdf	

Windstorm Hazard Assessment

Hazard Identification

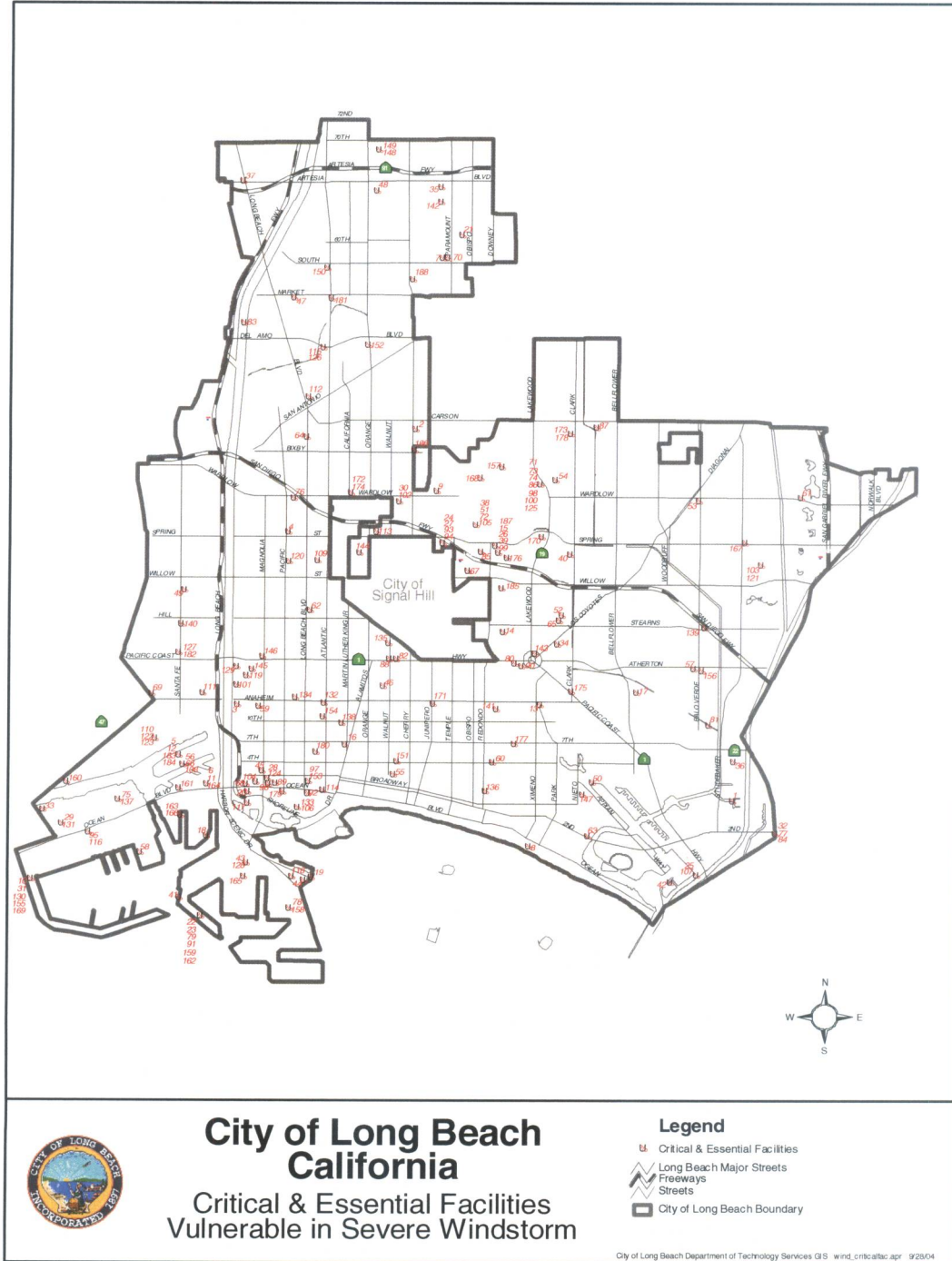
A windstorm event in the region can range from short term microburst activity lasting only minutes to a long duration Santa Ana wind condition that can last for several days as in the case of the January 2003 Santa Ana wind event. Windstorms can cause extensive damage including heavy tree stands, exposed coastal properties, road and highway infrastructure, and critical utility facilities. Heavy tourist traffic on the State and Local beach property is at great risk during windstorm activity.

Map 8-1 shows clearly the direction of the Santa Ana winds as they travel from the stable, high-pressure weather system called the Great Basin High through the canyons and towards the low-pressure system off the Pacific. Clearly the area of the City of Long Beach is in the direct path of the ocean-bound Santa Ana winds.

Vulnerability and Risk

With an analysis of the high wind and tornado events depicted in the "Local History" section, we can deduce the common windstorm impact areas including impacts on life, property, utilities, infrastructure and transportation. Additionally, if a windstorm disrupts power to local residential communities, the American Red Cross and City resources might be called upon for care and shelter duties. Displacing residents and utilizing City resources for shelter staffing and disaster cleanup can cause an economic hardship on the community.

**Map 8-1: Facilities Map - Severe Windstorm
(Source: City of Long Beach GIS)**



Community Windstorm Issues

What is Susceptible to Windstorms?

Life and Property

Based on the history of the region, windstorm events can be expected, perhaps annually, across widespread areas of the region which can be adversely impacted during a windstorm event. This can result in the involvement of City of Long Beach emergency response personnel during a wide-ranging windstorm or microburst tornadic activity. Both residential and commercial structures with weak reinforcement are susceptible to damage. Wind pressure can create a direct and frontal assault on a structure, pushing walls, doors, and windows inward. Conversely, passing currents can create lift suction forces that pull building components and surfaces outward. With extreme wind forces, the roof or entire building can fail causing considerable damage.

Debris carried along by extreme winds can directly contribute to loss of life and indirectly to the failure of protective building envelopes, siding, or walls. When severe windstorms strike a community, downed trees, power lines, and damaged property can be major hindrances to emergency response and disaster recovery.

The Beaufort Scale below, coined and developed by Sir Francis Beaufort in 1805, illustrates the effect that varying wind speed can have on sea swells and structures:

Table 8-5: Beaufort Scale

BEAUFORT SCALE		
Beaufort Force	Speed (mph)	Wind Description - State of Sea - Effects on Land
0	Less 1	Calm - Mirror-like - Smoke rises vertically
1	1-3	Light - Air Ripples look like scales; No crests of foam - Smoke drift shows direction of wind, but wind vanes do not
2	4-7	Light Breeze - Small but pronounced wavelets; Crests do not break - Wind vanes move; Leaves rustle; You can feel wind on the face
3	8-12	Gentle Breeze - Large Wavelets; Crests break; Glassy foam; A few whitecaps - Leaves and small twigs move constantly; Small, light flags are extended
4	13-18	Moderate Breeze - Longer waves; Whitecaps - Wind lifts dust and loose paper; Small branches move

5	19-24	Fresh Breeze - Moderate, long waves; Many whitecaps; Some spray - Small trees with leaves begin to move
6	25-31	Strong Breeze - Some large waves; Crests of white foam; Spray - Large branches move; Telegraph wires whistle; Hard to hold umbrellas
7	32-38	Near Gale - White foam from breaking waves blows in streaks with the wind - Whole trees move; Resistance felt walking into wind
8	39-46	Gale - Waves high and moderately long; Crests break into spin drift, blowing foam in well marked streaks - Twigs and small branches break off trees; Difficult to walk
9	47-54	Strong Gale - High waves with wave crests that tumble; Dense streaks of foam in wind; Poor visibility from spray - Slight structural damage
10	55-63	Storm - Very high waves with long, curling crests; Sea surface appears white from blowing foam; Heavy tumbling of sea; Poor visibility - Trees broken or uprooted; Considerable structural damage
11	64-73	Violent Storm - Waves high enough to hide small and medium sized ships; Sea covered with patches of white foam; Edges of wave crests blown into froth; Poor visibility - Seldom experienced inland; Considerable structural damage
12	>74	Hurricane - Sea white with spray. Foam and spray render visibility almost non-existent - Widespread damage. Very rarely experienced on land.

Source: <http://www.compuweather.com/decoder-charts.html>

Disruption of Critical Services

Critical facilities include police stations, fire stations, hospitals, shelters, and other facilities that provide important services to the community. These facilities and their services need to be functional after an earthquake event.

Utilities

Historically, falling trees have been the major cause of power outages in the region. Windstorms such as strong microbursts and Santa Ana Wind conditions can cause flying debris and downed utility lines. For example, tree limbs breaking in winds of only 45 mph can be thrown over 75 feet. As such, overhead power lines can be damaged even in relatively minor windstorm events. Falling trees can bring electric power lines down to the pavement, creating the possibility of lethal electric shock. Rising population growth and new infrastructure in the region creates a higher probability for damage to occur from windstorms as more life and property are exposed to risk.

Infrastructure

Windstorms can damage buildings, power lines, and other property and infrastructure due to falling trees and branches. During wet winters, saturated soils cause trees to become less stable and more vulnerable to uprooting from

high winds.

Windstorms can result in collapsed or damaged buildings or blocked roads and bridges, damaged traffic signals, streetlights, and parks, among others. Roads blocked by fallen trees during a windstorm may have severe consequences to people who need access to emergency services. Emergency response operations can be complicated when roads are blocked or when power supplies are interrupted. Industry and commerce can suffer losses from interruptions in electric services and from extended road closures. They can also sustain direct losses to buildings, personnel, and other vital equipment. There are direct consequences to the local economy resulting from windstorms related to both physical damages and interrupted services.

Increased Fire Threat

Perhaps the greatest danger from windstorm activity in southern California comes from the combination of the Santa Ana winds with the major fires that occur every few years in the urban/wildland interface. With the Santa Ana winds driving the flames, the speed and reach of the flames is even greater than in times of calm wind conditions. The higher fire hazard raised by a Santa Ana wind condition requires that even more care and attention be paid to proper brush clearances on property in the wildland/urban interface areas.

Transportation

Windstorm activity can have an impact on local transportation in addition to the problems caused by downed trees and electrical wires blocking streets and highways. During periods of extremely strong Santa Ana winds, major highways can be temporarily closed to truck and recreational vehicle traffic. However, typically these disruptions are not long lasting, nor do they carry a severe long term economic impact on the region.

End Notes:

1 <http://nimbo.wrh.noaa.gov/Sandiego/snawind.html>

2bid

3Keith C. Heidorn at <http://www.suite101.com/article.cfm/13646/100918>,
June 1, 2003

4bid

5bid

6bid

7www.cbsnews.com, January 8, 2003

8www.cbsnews.com/stories/2003/01/06/national/

Special Thanks to Jacob Green, Assistant to the Emergency Services Coordinator, City of Fountain Valley/Huntington Beach Hazard Mitigation Planning Committee