SECTION 9: LANDSLIDES

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

Landslides are a serious geologic hazard in almost every state in the United States. Nationally, landslides cause 25 to 50 deaths each year. The best estimate of direct and indirect costs of landslide damage in the United States ranges between $1 and $2 billion annually. In California, landslides are a significant problem, in part because of the region's seismic activity, and in part because the region is underlain by weak soils and rocks, especially when saturated. Some landslides result in private property damage, whereas other landslides impact transportation corridors, fuel and energy conduits, and communication facilities. They can also pose a serious threat to human life.

The City of Newport Beach is located in an area of widely diverse terrain at the southern margin of the geographic area known as the Los Angeles Basin. The City is bounded on the northwest by the broad, nearly flat-lying coastal plain of Orange County – the great outwash plain of the Santa Ana River. To the northeast lie the foothills of the Santa Ana Mountains and the smaller Tustin Plain. Rugged coastal mountains are present to the south.

The City's landscape can best be described by geographic area, each reflective of its distinct topographic features. The central and northwestern portions of the City are situated on a broad mesa that extends southeastward to join the San Joaquin Hills. Commonly known as Newport Mesa, this upland is comprised of a series of Pleistocene-aged marine terraces uplifted to their present elevation. The mesa has been deeply dissected by stream erosion, resulting in moderate to steep bluffs along the Upper Newport Bay estuary. The nearly flat-topped surface rises from about 50 to 75 feet above mean sea level at the northern end of the estuary in the Santa Ana Heights area, to about 100 feet above sea level in the Newport Heights, Westcliff, and Eastbluff areas.

Along the southwestern margin of the City, sediments flowing from the two major drainage courses that transect the mesa have formed the beaches, sandbars, and mudflats of Newport Bay and West Newport. These lowland areas were significantly modified during the last century in order to deepen channels for navigation and form habitable islands. Balboa Peninsula, a barrier beach that protects the bay, was once the site of extensive low sand dunes.

In the southern part of the City, the San Joaquin Hills rise abruptly from the sea, separated from the present shoreline by a relatively flat, narrow shelf. Originally formed by wave abrasion, this terrace or platform is now elevated well above the water and is bounded by steep bluffs along the shoreline. Elevations of the Balboa Peninsula and the harbor islands generally range from about 5 to 10 feet above sea level. The coastal platform occupied by Corona Del Mar is at an elevation of about 95 to 100 feet above sea level, and the San Joaquin Hills, site of the Newport Coast development area, rise to an elevation of 1,164 feet at Signal Peak.

The two major drainages that have contributed greatly to the development of the City's landforms are the Santa Ana River and San Diego Creek. At one time, the natural course of the Santa Ana River hugged the western side of Newport Mesa, carving steep bluffs and feeding sediment into Newport Bay. In an attempt to reduce flooding on the coastal plain, the river was confined to man-made levees and channels by the early 1920s. North of the City, numerous streams draining the foothills, including Peters Canyon Wash, Rattlesnake Wash, Hicks Canyon, Agua Chinon, and Serrano Creek, merged with San Diego Creek and collectively cut a wide channel through the mesa, later filling it with sediment (Upper Newport Bay and the harbor area). The collected drainages are now contained in the man-made San Diego Creek Channel, and directed into Upper Newport Bay near the intersection of Jamboree Road and University Drive. The Bay also receives water from the Santa Ana Delhi Channel near Irvine Avenue and Mesa Drive.

The portion of the San Joaquin Hills that lies within the City is drained by several deep canyons, including Buck Gully, Los Trancos Canyon, and Muddy Canyon, as well as numerous smaller, unnamed canyons. Carrying significant amounts of water only during the winter, these streams flow directly to the Pacific Ocean. Drainage courses on the north side of the hills, including Bonita and Coyote Creeks, are tributaries of San Diego Creek.

Development in the City began in the late 1800s with the arrival of the railroads and the McFadden (Newport) Pier. Development gradually spread outward from the rail lines and beaches, eventually covering most of Newport Mesa and the low hills to the south. More recently, residential developments and a major transportation corridor (State Route 73) made significant advances into the rugged terrain of the San Joaquin Hills. These types of projects require major earthwork activities, typically involving the movement of millions of cubic yards of earth. Because the severity of geologic hazards increases in the hills, corrective grading often accounts for a significant portion of the overall yardage.

The physical features described in the previous paragraphs are a reflection of the geologic and climatic processes that have played upon this region in the past few million years. The City of Newport Beach lies at the northern end of the Peninsular Ranges, a geologic/geomorphic province characterized by a northwest-trending structural grain aligned with the San Andreas fault, and represented by a series of northwest-trending faults, mountain ranges and valleys stretching from Orange County to the Mexican border. Displacements on faults in this region are mainly of the strike-slip type, and where they have been most recently active, they have deformed the landscape and altered drainage patterns. An example of such faulting in the Newport Beach area is the Newport-Inglewood fault zone, which trends in a southeasterly direction across the Los Angeles Basin, and leaves the coastline at the northwestern corner of the City, continuing offshore to the south. Predominantly right-lateral in movement, the Newport-Inglewood fault is responsible for uplifting the chain of low hills and mesas that extends from Beverly Hills to Newport Beach across the relatively flat coastal plain. The location and structure of the fault zone is known primarily from a compilation of surface mapping and deep, subsurface data, driven initially by an interest in oil exploration (all of the hills and mesas, including Newport Mesa, have yielded petroleum), and later by a shift toward evaluating earthquake hazards. The fault is an active structure and was the source of the 1933 M6.4 Long Beach earthquake. Despite the name, this earthquake was actually centered closer to Newport Beach, near the mouth of the Santa Ana River (Hauksson and Gross, 1991).

The San Joaquin Hills are the westernmost range in the Peninsular Ranges province. The hills are structurally complex, consisting of tilted fault blocks, and numerous north and northwest-trending Tertiary- and Quaternary-age faults. Within the hills, the major structural feature is the Pelican Hill fault zone, which trends northwesterly from Emerald Bay to the Big Canyon area. The fault zone is several hundred feet wide, and has left the adjacent bedrock in a highly sheared, folded, and fractured condition (Munro, 1992; Barrie et al., 1992). The Pelican Hill fault, as well as the other faults exposed in the hills, has largely been determined to be inactive during Holocene time (Clark et al., 1986).

In recent years, scientists have discovered that the northern end of the province, primarily the Los Angeles metropolitan area, is underlain by a series of deep-seated, low-angle thrust faults. When these faults do not reach the surface, they are called "blind thrusts." Faults of this type are thought to be responsible for the uplift of many of the low hills in the Los Angeles Basin, such as the Repetto or Montebello Hills. Previously undetected blind thrust faults were responsible for the M5.9 Whittier Narrows earthquake in 1987, and the destructive M6.7 Northridge earthquake in 1994.

It has long been recognized that the San Joaquin Hills are part of a northwest-trending anticline (a convex fold) that extends from San Juan Capistrano to the Huntington Mesa (Vedder et al., 1957; Vedder, 1975). Research conducted in the past two to three decades has suggested that the anticline, which includes the Newport and Huntington Mesas as well as the San Joaquin Hills, is part of a structure that is being uplifted by an active blind thrust fault that dips southward beneath the area (Grant et al., 1999). The growth of the San Joaquin Hills has been recorded in remnants of marine terraces of various ages that cap the northern and western slopes. These terraces consist of wave-eroded, sediment-covered platforms (similar to the one present at the base of the hills today) that have been uplifted as the hills rose above sea level. Based on measurements of terrace elevations and dating of the sediments, uplift of the hills is thought to have started approximately 1.2 million years ago, and is believed to have continued into the Holocene at a rate of about 0.25 meters per 1,000 years (Barrie et al., 1992; Grant et al., 1999), although additional research is being conducted to confirm this. Recognition of the San Joaquin Hills thrust fault extends the area of active blind thrusts and associated folding southward from Los Angeles into the Newport Beach area (Grant et al., 1999). Furthermore, recent studies have suggested that there are buried thrust faults offshore, in the Southern California Continental Borderland, that are also accommodating crustal shortening (Rivero et al., 2000, 2011). If this is the case, then there are additional potential seismic sources offshore that could cause strong ground shaking and associated secondary hazards, such as landsliding, in Newport Beach.

What is a Landslide?

Landslides are downslope movements of relatively large landmasses, either as nearly intact bedrock blocks, or as jumbled mixes of bedrock blocks, fragments, debris, and soil. 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, and in general, landslides can be broken down into two categories: 1) rapidly moving (mud or debris flows, rock falls, and rock topples), and 2) slow moving (earth flows and slumps). Movement of larger landmasses can range from rapid to very slow. Rapidly moving landslides or debris flows pose 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 or worse. Slow moving landslides can cause significant property damage, but are less likely to result in serious human injuries.

Geologists also describe the type of movement of a landslide as either 1) translational (where movement occurs along a relatively planar dipping surface), 2) rotational (where sliding material moves along a curved surface) or 3) wedge (where movement occurs on a wedge-shaped block formed by intersecting planes of weakness, such as fractures, faults and bedding). 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 as mentioned above, speed of movement. Shallow slides are generally about 15 feet or less in depth and involve the near surface soil, and possibly the underlying weathered bedrock. Deeper slides most often consist of bedrock blocks, either severely broken or relatively intact, depending on the bedrock structure and mode of failure.

Landslides can be initiated by rainfall, earthquakes, volcanic activity, changes in ground water, disturbance and change of a slope by man-made construction activities, or any combination of these factors. Landslides can also occur underwater, causing large waves that could damage lowlying coastal areas. The potential for slope failure is dependent on many factors, including slope height, slope steepness, shear strength and orientation of the underlying geologic unit, as well as moisture content. For example, water can increase the plasticity of weak clays lining joints or shears, forming planes of weakness along which a landmass can fail.

For engineering of earth materials, these factors are combined in calculations to determine if a slope meets a minimum safety standard. The generally accepted standard is a factor of safety of 1.5 or greater (where 1.0 is equilibrium, and less than 1.0 is failure). Natural slopes, graded slopes, or graded/natural slope combinations must meet these minimum engineering standards where they impact planned homes, subdivisions, or other types of developments. Slopes adjacent to areas where the risk of economic losses from landsliding is small, such as parks and mountain roadways, are often allowed a lesser factor of safety. From an engineering perspective, landslides are generally unstable (may be subject to reactivation), and may be compressible, especially around the margins, which are typically highly disturbed and broken. The headscarp area above the landslide mass is also unstable, since it is typically oversteepened, cracked, and subject to additional failures. Numerous landslides and suspected landslides consisting of highly fragmented, jumbled bedrock debris as well as largely coherent bedrock blocks were mapped in the San Joaquin Hills. Many of the steeper hillsides in the San Joaquin Hills likely did not meet the minimum factor of safety, and slope stabilization was needed or will be needed prior to development of these areas. In the now-graded areas of Newport Coast, several of these landslide-prone areas are expected to have been made more stable through a variety of engineering methods prior to development.

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 at 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.

What is a Debris Flow?

This type of failure is the most dangerous and destructive of all types of slope failure. A debris flow (also called mudflow, mudslide, and debris avalanche) is a rapidly moving slurry of water, mud, rock, vegetation and debris. Larger debris flows are capable of moving trees, large boulders, and even cars. This type of failure is especially dangerous as it can move at great speeds, is capable of crushing buildings, and can strike with very little warning. The development of debris flows is strongly tied to exceptional storm periods of prolonged rainfall. Failure occurs during an intense rainfall event, following saturation of the soil by previous rains.

A debris flow most commonly originates as a soil slip in the rounded, soil-filled "hollow" at the head of a drainage swale or ravine. The rigid soil mass is deformed into a viscous fluid that moves down the drainage, incorporating into the flow additional soil and vegetation scoured from the channel. Debris flows also occur on canyon walls, often in soil-filled swales that do not have topographic expression. The velocity of the flow depends on the viscosity, slope gradient, height of the slope, roughness and gradient of the channel, and the effects of baffling by vegetation. Even relatively small amounts of debris can cause damage from inundation and/or impact (Ellen and Fleming, 1987; Reneau and Dietrich, 1987). Recognition of this hazard led FEMA to modify its National Flood Insurance Program to include inundation by "mudslides."

Watersheds that have been recently burned typically yield greater amounts of soil and debris than those that have not burned. Erosion rates during the first year after a fire are estimated to be 15 to 35 times greater than normal, and peak discharge rates range from 2 to 35 times higher. These rates drop abruptly in the second year, and return to normal after about 5 years (Tan, 1998). In addition, debris flows in burned areas are unusual in that they can occur in response to small storms and do not require a long period of antecedent rainfall. These kinds of flows are common in small gullies and ravines during the first rains after a burn, and can become catastrophic when a severe burn is followed by an intense storm season (Wells, 1987). The United States Geological Survey (USGS), as part of its National Landslide Hazards Program, has been developing tools and methodologies to identify and quantify slope stability hazards posed by burned watersheds. These tools include the installation of instruments in recently burned watersheds and canyons to collect data on rainfall, flow stage, soil moisture, and other parameters. The data collected help "advance the understanding of post-fire runoff, erosion, and debris flow generation . . . and provide information from the burned area to the National Weather Service for warning decision-making" (http://landslides.usgs.gov/monitoring/). Such tools help communities with emergency planning and in dealing with post-fire rehabilitation (USGS, 2001).

Historic Southern California Landslides

Historically, there have been many landslides in the Southern California area. Landslides recorded in the 20th century alone caused losses of more than $5 billion (in 2000 dollars). Many of these landslides have occurred after particularly wet winters, others in response to strong ground shaking during an earthquake. Some of the most dramatic of these cases are briefly described below (Highland and Schuster, undated).

1956 Portuguese Bend Landslide, Palos Verdes

Cost: $14.6 million (2000 dollars), on California Highway 14 in the Palos Verdes Hills. The Portuguese Bend landslide is a reactivated ancient slide that began its modern movement in August 1956, when displacement was noticed at its northeast margin. Reactivation is blamed in part to human activity, including the extensive use of septic tanks and seepage pits for residential structures. Movement gradually extended downslope so that the entire eastern edge of the slide mass was moving within six weeks. By the summer of 1957, the entire mass was sliding towards the sea.

1969 Glendora, Los Angeles County

Cost: $26.9 million (2000 dollars), in Los Angeles County. The winter of 1969 was one of the wettest on record in the Southern California area. The rain caused many of the streams draining the San Gabriel Mountains to overflow, resulting in debris flows that damaged 175 houses in the Glendora area alone.

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

Cost, $14.6 million (2000 dollars); 100 houses damaged due to debris flows.

1978 Bluebird Canyon, Orange County

Cost: $52.7 million (2000 dollars); 60 houses destroyed or damaged. On October 2, 1978, a portion of the Bluebird Canyon slope gave way, in great part due to the unusually heavy rains in March that 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.

1979 Big Rock, Los Angeles County

Cost: approximately $1.08 billion (2000 dollars; rockslide that caused damage to California Highway 1 (Pacific Coast Highway) in the Malibu area. High groundwater levels attributed to the use of septic tanks is considered a leading cause of this landslide.

1980 Southern California Landslides

Cost: $1.1 billion in damage (2000 dollars). Heavy winter rainfall in 1979-80 caused damage in six Southern California counties. A sequence of five days of continuous rain that started on February 8 dropped more than 7 inches of water by February 14. Slope failures began 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.

1978-1979, 1980 San Diego County

San Diego County experienced major damage from storms in 1978, 1979, and 1979-80, as did neighboring areas of Los Angeles and Orange Counties. One hundred and twenty landslides were reported to have occurred in San Diego County during these two years. Rainfall for the rainy seasons of 1978-79 and 1979-80 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 geologic unit known to be slide-prone. [Of the nine landslides that caused damage in excess of $1 million in the northern part of San Diego County, seven occurred in the Friars Formation, and two in the Santiago Formation.]

1983 San Clemente, Orange County

Cost: $65 million (2000 dollars), California Highway 1. Litigation associated with this landslide ultimately cost approximately $43.7 million (2000 dollars).

1983 Big Rock Mesa, Malibu, Los Angeles County

Cost: $706 million (2000 dollars) in legal claims; 13 houses condemned and 300 more threatened due to rockslide triggered by intense rainfall.

1994 Northridge Earthquake Landslides

As a result of the magnitude 6.7 Northridge earthquake, more than 11,000 landslides occurred over an area of 10,000 km^2. Most landslides occurred in the Santa Susana Mountains and in mountains north of the Santa Clara River Valley. The landslides destroyed dozens of homes, blocked roads, and damaged oil-field infrastructure.

1995 Los Angeles and Ventura Counties Landslides

Above-normal rainfall in March triggered damaging debris flows, deep-seated landslides, and flooding. Several deep-seated landslides were triggered by the storms, the most notable being the La Conchita landslide, which in combination with a local debris flow, destroyed or badly damaged 14 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 two years before.

2005 La Conchita Landslide, Ventura County

Cost – undetermined yet, but most likely in the billions, including litigation. On January 10, 2005 a landslide struck the sea-side community of La Conchita destroying 13 homes, severely damaging 23 others, and killing 10 people. The landslide occurred in an area known for prior landslide activity (more recently in 1995), and was the direct result of intense rainfall in the area, compounded by weak sediments and steep slopes. The landslide material failed almost simultaneously, and descended down the slope as a highly fluid, rapidly moving debris flow, with top speeds estimated at 30 feet per second (ft/sec) (Jibson, 2005).

2005 Blue Bird Canyon Landslide, Laguna Beach, Orange County

Cost – undetermined yet, but probably in the billions, in great part due to litigation. On June 1, a landslide began moving in the area, almost certainly in response to the extremely wet winter rains earlier that year, in January and February. This landslide occurred in the same general area as the 1978 landslides. 17 houses were destroyed, 11 were damaged, and another 23 were threatened. Fortunately, no one died or was seriously hurt.

Conditions Conducive to Slope Failures

Locations at risk from landslides or debris flows include the following:

- ✓ On or close to steep hills;
- ✓ Steep road-cuts or excavations;
- ✓ 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);
- ✓ Steep areas where surface runoff is channeled, such as below culverts, V-shaped valleys, canyon bottoms, and steep stream channels;
- ✓ Fan-shaped areas of sediment and boulder accumulation at the outlets of canyons; and
- ✓ Canyon areas below hillside and mountains that have recently (within 1-6 years) been subjected to a wildland fire.

The conditions leading to failure can be varied. The most common of these are described in detail below.

Natural Conditions

Natural processes can cause landslides or re-activate historical and pre-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.

Weathering of geologic materials produces conditions conducive to landslides, while human activity often further exacerbates many landslide problems. Many landslides are difficult to mitigate, particularly in areas of large historic movement with weak underlying geologic materials.

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. Rock falls 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.

As the list of historical landslides suggests, 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.

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 that combine to form a sheet of mud and debris. Debris flows can often originate miles away, upstream, from a developed area, and approach the built environment at the mouth of a canyon at a high rate of speed with little warning.

Impacts of Development

As communities modify their 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, and without proper planning, landslide hazards would be even more common and more destructive. The increasing scarcity of buildable 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.

Thus, although landslides are a natural occurrence, human impacts can substantially affect the potential for landslide failures to occur. 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. Grading for road construction and development can increase slope steepness. Other human activities effecting landslides include excavation, drainage and groundwater alterations, and changes in vegetation (as discussed further below). Proper planning and geotechnical engineering if applied judiciously, however, can be implemented to reduce the threat to people, property, and infrastructure posed by unstable slopes.

Excavation and Grading

Slope excavation is common in the development of home sites or roads on sloping terrain. Grading these slopes sometimes results in slopes 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, both along the road cut and the road fill sections. Landslides occurring below new construction sites are indicators of the potential impacts stemming from excavation. Alternatively, if unstable slope conditions are recognized and engineered for during grading, originally unstable or marginally stable slopes can be made safer.

Alterations to Drainage and Groundwater Systems

Water flowing through or above ground is often the trigger of 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 and seepage fields 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 surfaces (such as concrete- or asphalt-paved roads) 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 runoff flow. Ground saturation and concentrated velocity flow are major causes of slope problems and may trigger landslides.

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 non-native ground covers require extensive irrigation to remain green. As a result, clearing and replacement of native ground covers with non-native covers can lead to an increase in slope failures.

Landslide Hazard Assessment

Hazard Identification

Identifying hazardous locations is an essential step towards implementing more informed mitigation activities. Evidence of past slope failures are found throughout the San Joaquin Hills in Newport Beach. In fact, landslides have been and remain a significant risk as development reaches higher elevations within the hills. Although an active landslide tends to affect a relatively small area (as compared to a damaging earthquake), and is generally a problem for only a short period of time, the dollar loss can be high. Insurance policies typically do not cover landslide damage, and this can add to the anguish of the affected property owners.

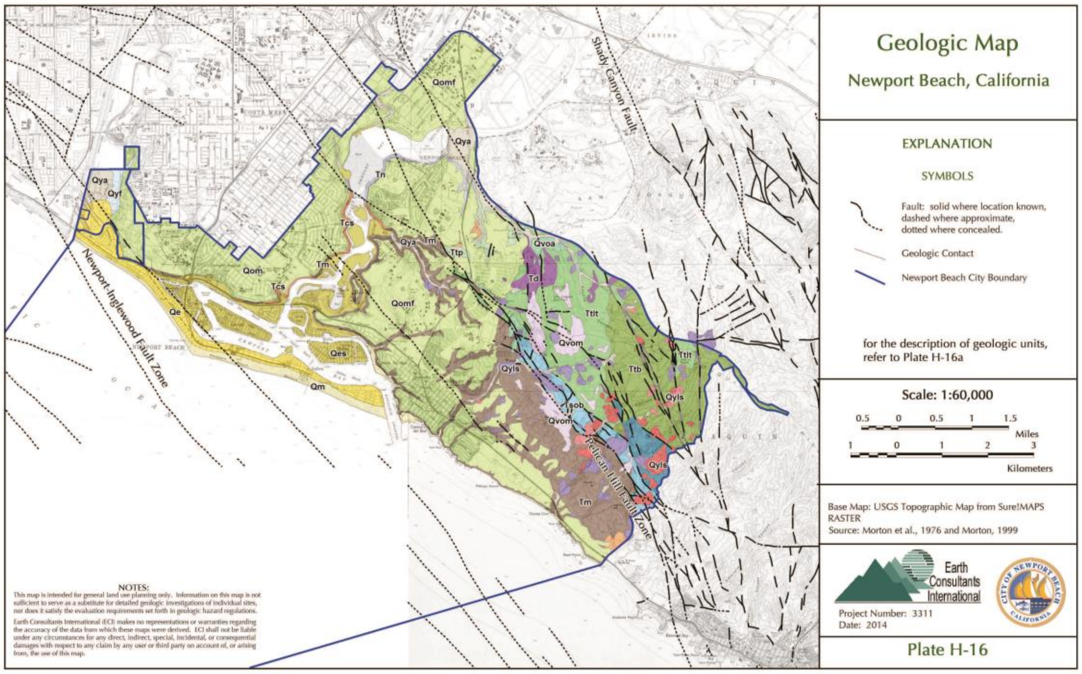
As mentioned before, the San Joaquin Hills contain numerous landslides or suspected landslides composed of highly fragmented, jumbled bedrock debris as well as largely coherent bedrock blocks. Landslides are typically identified by their distinctive morphology, which most often includes a steep, arcuate headscarp, undulating or relatively flat-topped head, and a blocked or diverted drainage at the toe. Most of the slides appear to be rotational failures, occurring in steep natural slopes composed of bedrock weakened by the intense fracturing, shearing and folding in or near the Pelican Hill fault zone. Some of the slides may be block glides associated with the failure of unsupported weak bedding planes. The larger slides are probably more than a hundred feet thick. Landslide materials are commonly porous and very weathered in the upper portions and along the margins. They may also have open fractures and joints. The head of the slide may have a graben (pull-apart area) that has been filled with soil, bedrock blocks and fragments.

Most of the landslides in the San Joaquin Hills are pre-historic in age. The combination of a low sea level in Pleistocene time (when much of the Earth's water was trapped in great ice sheets) and regional tectonic uplift has resulted in the oversteepening of slopes facing small to large stream channels. This, along with the presence of weak bedrock materials, severe deformation associated with the numerous faults that traverse the hills, and a wetter prehistoric climate, have been the major factors contributing to the occurrence of the large number of landslides that cover the hills. Some of these slides have been reactivated in the late Holocene (approximately the past 5,000 years) and, if left untreated, can pose a significant hazard to development.

All the bedrock formations in the San Joaquin Hills have been involved in landsliding, however the most susceptible formations are those that are largely composed of siltstone, claystone, mudstone, and shale, such as the Monterey, Topanga (Los Trancos member), and Vaqueros Formations (see Map 9-1 and Plates H-16 and H-16a). These units are present in the central, southern, and western portions of the hills. The San Onofre Formation, normally resistant to landsliding, occurs as a sheared faulted block within the Pelican Hills fault zone, and as a consequence, has produced several large landslides.

Map 9-1: Geologic Map of Newport Beach

The red zones show areas still undeveloped where landslides have been mapped. Previously mapped landslides in now-graded areas are shown in purple. (For a larger map and an explanation of the geologic units, refer to Plates H-16 and H-16a, respectively.)



Base Map: USGS Topographic Map from Sure!MAPS RASTER
Source: Morton et al., 1976 and Morton, 1999

NOTES:

This map is intended for general land use planning only. Information on this map is not sufficient to serve as a substitute for detailed geologic investigations of individual sites, nor does it satisfy the evaluation requirements set forth in geologic hazard regulations.

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The Capistrano siltstone is notorious for large landslides in southern Orange County, where it underlies vast areas of hillside terrain. In Newport Beach, this formation is limited to scattered outcrops along the western bluffs of Newport Bay, and is covered by a protective cap of marine terrace deposits. Consequently, large landslides are not present in this area, and slope instability is generally limited to surficial failures.

Surficial slumps and slides are too small to map at the scale of Map 9-1, however they are common within the hills, typically occurring in the thick soils and deeply weathered bedrock near the base of steep slopes. Soil slips are common throughout the hills during winters of particularly heavy and prolonged rainfall, such as the storms of 1998 that caused several debris flows in the Back Bay Bluffs area.

Much of the accumulated sediment in canyon bottoms, as well as small sediment fans at the mouths of tributary drainages, was probably deposited in mud slurries or debris flows. Catastrophic debris flows, however, have not been reported for the Newport Beach area, probably because most development in the City occurs on elevated areas, rather than vulnerable locations at the base of natural slopes and in canyon bottoms.

Slopes that are the most susceptible to creep are those composed of weak, fine-grained geologic materials, similar to those that are susceptible to landsliding. Fill slopes constructed with materials excavated from these bedrock units may also show signs of creep over time.

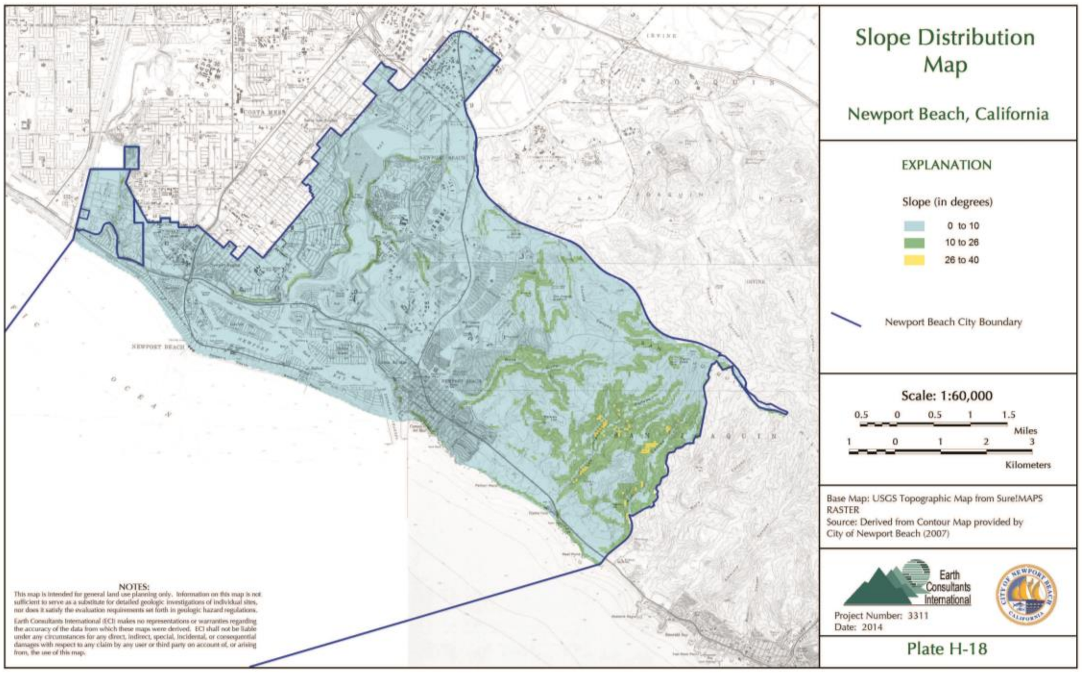
Vulnerability and Risk

A vulnerability assessment for landslides can help predict how different types of property and population groups will be affected by the hazard of unstable slopes. Data that include specific landslide- and debris flow-prone locations in the City can be used to assess the population and total value of property at risk from future landslide occurrences.

The potential for slope failure is dependent on many factors and their interrelationships. Some of the most important factors include slope height, slope steepness, sheer strength, and orientation of weak layers in the underlying geologic units, as well as pore water pressures. [For a map showing steep slopes in the Newport Beach area, refer to Map 9-2 and Plate H-18. This map takes into consideration the grading that has been done in the San Joaquin Hills; the slope height and steepness considered in the analysis is based on a 2007 topographic map provided by the City that shows many of the originally steep slopes have been modified to make them flatter and thus more stable.] Joints and shears, which weaken the rock fabric, allow water to infiltrate deeply into the bedrock, which in turn leads to an increase in the weathering of the rock, increase in pore pressures, increase in the plasticity of weak clays, and an increase in the weight of the landmass. For engineering of earth materials, these factors are combined in calculations to determine if a slope meets a minimum safety standard. The generally accepted standard is a factor of safety of 1.5 or greater (where 1.0 equilibrium, and less than 1.0 is failure).

Map 9-2: Slope Distribution Map of Newport Beach

(for a larger version of this map, refer to Plate H-18 in Appendix H)



Base Map: USGS Topographic Map from Sure!MAPS RASTER
Source: Derived from Contour Map provided by City of Newport Beach (2007)

NOTES:
This map is intended for general land use planning only. Information on this map is not sufficient to serve as a substitute for detailed geologic investigations of individual sites, nor does it satisfy the evaluation requirements set forth in geologic hazard regulations.
Earth Consultants International (ECI) makes no representations or warranties regarding the accuracy of the data from which these maps were derived. ECI shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to any claim by any user or third party on account of, or arising from, the use of this map.

Despite the abundance of landslides and relatively recent spread of new development into the San Joaquin Hills, damage from slope failures in Newport Beach has been relatively small compared to other hillside communities, and has more often occurred in older developments. No landslides or slope failures of consequence were reported in Newport Beach during the period between 2008 and 2013.

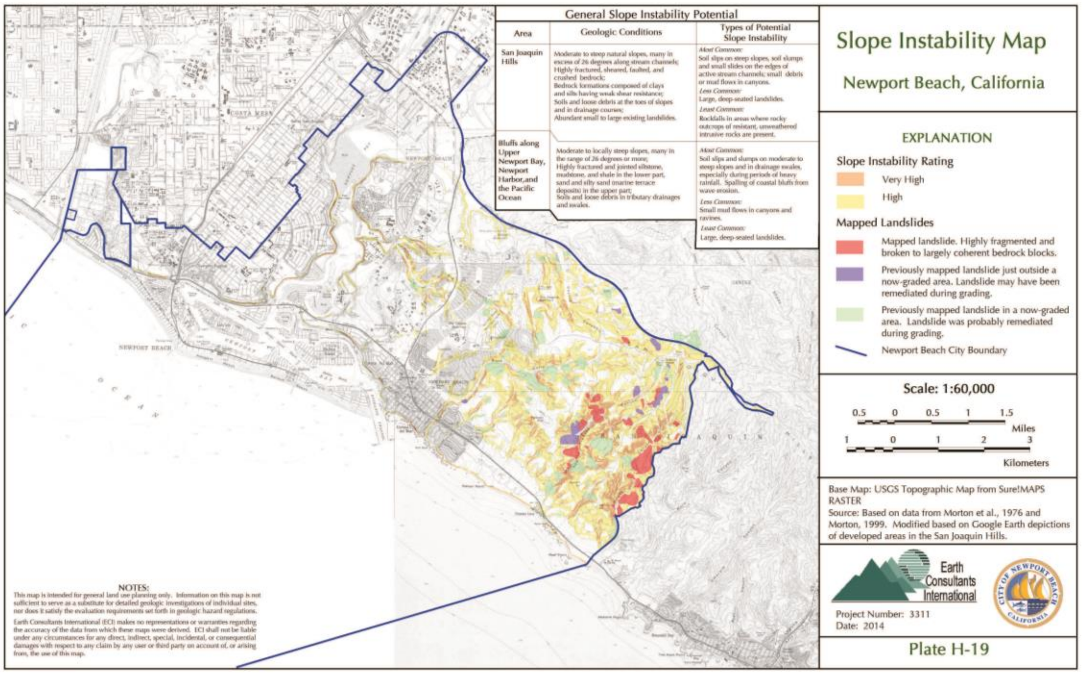
Some of the areas where landslides have historically been an issue include the Spyglass Hill area, and Galaxy Drive, along the bluffs facing the bay. The limited landslide damage in Newport Beach can probably be attributed to land development fundamentals that have evolved and improved over the last few decades, including stricter hillside grading ordinances, sound project design that avoids severely hazardous areas, soil engineering practices that include detailed preliminary investigations and oversight during grading, and effective agency review of hillside grading projects. The recent trend toward saving biologically rich canyon habitats has the added benefit of keeping developments out of the path of potential slope failures.

Nevertheless, developments at the top of natural slopes may be impacted by slope failures. Even if a slope failure does not reach the properties above, the visual impact will generally cause alarm to homeowners. The City's remaining natural hillsides and coastal bluff areas are generally vulnerable to the types of slope instability mentioned above. Table 9-1 below is a summary of the geologic conditions in various parts of the City that provide the environment for slope instability to occur. These conditions usually include such factors as terrain steepness, rock or soil type, condition of the rock (such as degree of fracturing and weathering), internal structures within the rock (such as bedding, foliation, faults) and the prior occurrence of slope failures. Catalysts that ultimately allow slope failures to occur in vulnerable terrain are most often water (heavy and prolonged rainfall, or leaky water pipes), erosion and undercutting by streams, man-made alterations to the slope, or seismic shaking. The information in Table 9-1 was used to make the Slope Instability Map (Map 9-3 and Plate H-19).

Table 9-1: General Slope Instability Potential Within the City of Newport Beach

Area	Geologic Conditions	Types of Potential Slope Instability
San Joaquin Hills	Moderate to steep natural slopes, many in excess of 26 degrees along stream channels; Highly fractured, sheared, faulted, and crushed bedrock; Bedrock formations composed of clays and silts having weak shear resistance; Soils and loose debris at the toes of slopes and in drainage courses; Abundant small to large existing landslides.	***Most Common:*** Soil slips on steep slopes, soil slumps and small slides on the edges of active stream channels; small debris or mudflows in canyons. ***Less Common:*** Large, deep-seated landslides. ***Least Common:*** Rockfalls in areas where rocky outcrops of resistant, unweathered intrusive rocks are present.
Bluffs along Upper Newport Bay, Newport Harbor, and the Pacific Ocean	Moderate to locally steep slopes, many in the range of 26 degrees or more; Highly fractured and jointed siltstone, mudstone, and shale in the lower part, sand and silty sand (marine terrace deposits) in the upper part; Soils and loose debris in tributary drainages and swales.	***Most Common:*** Soil slips and slumps on moderate to steep slopes and in drainage swales, especially during periods of heavy rainfall. Spalling of coastal bluffs from wave erosion. ***Less Common:*** Small mudflows in canyons and ravines. ***Least Common:*** Large, deep-seated landslides.

Map 9-3: Slope Instability Map of Newport Beach
Red zones are mapped landslides in still mostly undeveloped land; purple and green zones are previously mapped landslides in or near now-graded areas, respectively; orange zones have a very high instability rating, yellow areas have a high slope instability rating.
(For a larger version of this map refer to Plate H-19 in Appendix H.)



General Slope Instability Potential

Area	Geologic Conditions	Types of Potential Slope Instability
San Joaquin Hills	Moderate to steep natural slopes, many in excess of 26 degrees along stream channels; Highly fractured, sheared, faulted, and crushed bedrock; Bedrock formations composed of clays and silts having weak shear resistance; Soils and loose debris at the toes of slopes and in drainage courses; Abundant small to large existing landslides.	*Most Common:* Soil slips on steep slopes, soil slumps and small slides on the edges of active stream channels; small debris or mud flows in canyons. *Less Common:* Large, deep-seated landslides. *Least Common:* Rockfalls in areas where rocky outcrops of resistant, unweathered intrusive rocks are present.
Bluffs along Upper Newport Bay, Newport Harbor, and the Pacific Ocean	Moderate to locally steep slopes, many in the range of 26 degrees or more; Highly fractured and jointed siltstone, mudstone, and shale in the lower part, sand and silty sand (marine terrace deposits) in the upper part; Soils and loose debris in tributary drainages and swales.	*Most Common:* Soil slips and slumps on moderate to steep slopes and in drainage swales, especially during periods of heavy rainfall. Spalling of coastal bluffs from wave erosion. *Less Common:* Small mud flows in canyons and ravines. *Least Common:* Large, deep-seated landslides.

Base Map: USGS Topographic Map from Sure!MAPS RASTER
Source: Based on data from Morton et al., 1976 and Morton, 1999. Modified based on Google Earth depictions of developed areas in the San Joaquin Hills.

NOTES:
This map is intended for general land use planning only. Information on this map is not sufficient to serve as a substitute for detailed geologic investigations of individual sites, nor does it satisfy the evaluation requirements set forth in geologic hazard regulations.

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Community Landslide Issues

What is Susceptible to Landslides?

The City's hillsides are vulnerable to the types of slope instability mentioned above. Steep-sided slopes in the San Joaquin Hills and along deeply incised drainages may be locally susceptible to slope instability. Table 9-1 above is a general summary of the geologic conditions in various parts of the City that provide the environment for slope instability to occur.

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 were insufficient to conduct a risk analysis and the software needed to conduct this type of analysis was not available. However, a generalized review of the potentially unstable slope areas in the City, as shown on Map 9-3, and comparison with the location of the City's critical/essential facilities (Plate H-1) shows that most of the essential facilities in the City are not located in an area susceptible to slope instability. Fire Station No. 8 on Ridge Park Road is located in an area of high to very high slope instability susceptibility, and while the fire station site proper is not expected to be impacted by landsliding, some of the areas that it services, including access roads, could be impacted during periods of intense precipitation, or as a result of ground shaking.

Landslides can also affect utility services, transportation systems, and critical lifelines. Communities may suffer immediate damages and loss of service. For example, the road leading to San Joaquin Reservoir is flanked by terrain that in the past has experienced landslide activity, and where the slope instability susceptibility is mapped as high. During an earthquake, or as a result of intense and/or protracted rainfall, the road could be impacted by slope failures. 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 landslide movements as small as an inch or two. Some of these issues are discussed in more detail below.

Roads and Bridges

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 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.

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, gas, water, communication and sewer services 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.

Landslide Mitigation Activities

Landslide mitigation activities feature current mitigation programs and activities that have been and are being implemented by developers, residents, and State and City agencies. All proposed development projects require a site-specific geotechnical evaluation of any slopes that may impact the future use of the property. This includes existing slopes that are to remain, and any proposed graded slopes. The investigation typically includes borings to collect geologic data and soil samples, laboratory testing to determine soil strength parameters, and engineering calculations. Numerous soil-engineering methods are available for stabilizing slopes that pose a threat to development. These methods include designed buttresses (replacing the weak portion of the slope with engineered fill); reducing the height of the slope; designing the slope at a flatter gradient; and adding reinforcements such as soil cement or layers of geogrid (a tough polymeric net-like material that is placed between the horizontal layers of fill). Most slope stabilization methods include a subdrain system to remove excessive ground water from the slope area. If it is not feasible to mitigate the slope stability hazard, building setbacks are typically imposed.

For debris flows, assessment of this hazard for individual sites should focus on structures located or planned in vulnerable positions. This generally includes canyon areas; at the toes of steep, natural slopes; and at the mouth of small to large drainage channels. Mitigation of soil slips, earthflows, and debris flows is usually directed at containment (debris basins), or diversion (impact walls, deflection walls, diversion channels, and debris fences). A system of baffles may be added upstream to slow the velocity of a potential debris flow. Other methods include removal of the source material, placing subdrains in the source area to prevent pore water pressure buildup, or avoidance by restricting building to areas outside of the potential debris flow path.

There are numerous methods for mitigating rock falls. Choosing the best method depends on the geological conditions (i.e., slope height, steepness, fracture spacing, bedding orientation), safety, type and cost of construction repair, and aesthetics. A commonly used method is to regrade the slope. This ranges from locally trimming hazardous overhangs, to completely reconfiguring the slope to a more stable condition, possibly with the addition of benches to catch small rocks. Another group of methods focuses on holding the fractured rock in place by draping the slope with wire mesh, or by installing tensioned rock bolts, tie-back walls, or even retaining walls. Shotcrete is often used on slope faces to prevent raveling in highly fractured rock, but its primary purpose is to offer surface protection only. A third type of mitigation includes catchment devices at the toe of the slope, such as ditches, walls, or combinations of both. Designing the width of the catchment structure requires analysis of how the rock will fall. For instance, the slope gradient and roughness of the slope determines if rocks will fall, bounce, or roll to the bottom. Rock slope stabilization may also include the addition of drains in order to reduce water pressure within the slope (Wyllie and Norrish, 1996).

There are a number of options for management of potential slope instability in developed hillsides.

1. Complete a detailed survey and assessment of existing developments in areas recognized to be vulnerable to potential slope failures (for instance, the San Joaquin Hills).
2. Protect existing development and population where appropriate by physical controls such as drainage, slope-geometry modification, protective barriers, and retaining structures.
3. Implement monitoring or warning systems. For instance, in some recently burned watersheds, the USGS, in cooperation with the National Weather Service, installs and operates a system for real-time warnings for storm-related slope failures (Keefer et al., 1987; http://landslides.usgs.gov/monitoring/). Using a combination of tracking storm systems, measuring actual rainfall with a network of rain gauges, and comparing thresholds for the initiation of debris flows, they are able to issue Flash Flood/Debris Watches during the most intense storms, as necessary.
4. Post warning signs in areas of potential slope instability.
5. Encourage homeowners to use landscaping methods that help stabilize the hillsides.
6. Incorporate recommendations for potential slope instability into geologic and soil engineering reports for additions and new grading.
7. Educate the public about slope stability, including the importance of maintaining drainage devices. USGS Fact Sheet FS-071-00 (May, 2000) and the CGS Note 33 (November, 2001) provide public information on landslide and mudslide hazards. These are available on the internet (see Appendices A and B).

Landslide Resource Directory

City Resources

City of Newport Beach Community Development Department

100 Civic Center Drive
Newport Beach, California 92660
Ph: 949-644-3309

This City department administers the City's land use policies, as well as the City's zoning, building, subdivision, and environmental regulations to ensure the orderly physical growth of the community. The Planning and Building Divisions are responsible for planning, building plan checks, permit issuance, and inspection, among other programs. The City has received the highest grade possible from ISO (the Insurance Services Office) for building code enforcement.

County Resources

Orange County Department of Planning and Development Services

Development Processing Center
300 North Flower, Room 122
Santa Ana, CA 92705
Ph: 714-834-2626

State Resources

California Geological Survey, Southern California Regional Office

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

California Geological Survey, Headquarters

801 K Street, MS 12-30
Sacramento, CA 95814
Ph: 916-445-1923
Fax: 916-445-5718

California Division of Forestry, Headquarters

1416 9th Street
PO Box 944246
Sacramento, CA 94244-2460
Ph: 916-653-5123

California Department of Water Resources

1416 9th Street
Sacramento, CA 95814
Ph: 916-653-6192
Flood Operations Center Ph: 800-952-5530
Fax: 916-653-4684

Governor's Office of Emergency Services (Cal OES)

3650 Schriever Avenue
Mather, CA 95655
Ph: 916-845-8510; Fax: 916-845-8511
www.caloes.ca.gov

California Department of Transportation (Cal Trans) – District 12
3347 Michelson Drive, Suite 100
Irvine, CA 92612
Ph: 949-724-2000

Federal Resources and Programs

Federal Emergency Management Agency (FEMA) – Region IX
1111 Broadway, Suite 1200
Oakland, CA 94607-4052
Ph: 510-627-7100
Fax: 510-627-7112
Southern California Field Office Ph: 626-851-7900

Natural Resource Conservation Service (NRCS)
National Water and Climate Center
1201 NE Lloyd Boulevard, Suite 802
Portland, OR 97232-1274
Ph: 503-414-3031

US Geological Survey, National Landslide Information Center
Mail Stop 966, Box 25046
Denver Federal Center
Denver, CO 80225
Ph: 800-654-4966 or 303-273-8588
Fax: 303-273-8600

National Oceanic and Atmospheric Administration
National Weather Service
San Diego Weather Forecast Office
11440 W. Bernardo Court, Suite 230
San Diego, CA 92127
Ph: 858-675-8700

Publications

(for References, Refer to Appendix I)

Olshansky, Robert B., Planning for Hillside Development (1996) American Planning Association.
This document describes the history, purpose, and functions of hillside development and regulation and the role of planning, and provides excerpts from hillside plans, ordinances, and guidelines from communities throughout the US.

Olshansky, Robert B. & Rogers, J. David, Unstable Ground: Landslide Policy in the United States (1987) Ecology Law Quarterly.
This report discusses the history and policy of landslide mitigation in the US.

Public Assistance Debris Management Guide (July 2000) Federal Emergency Management Agency.
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 city emergency operations plans, developing strategies to ensure strong debris management is a way to integrate debris management within mitigation activities. The Guide is available in hard copy or on the FEMA website.

USGS Landslide Program Brochure. National Landslide Information Center (NLIC), United States Geologic Survey.

The brochure provides good, general information in simple terminology on the importance of landslide studies and a list of databases, outreach, and exhibits maintained by the NLLC. The brochure also includes information on the types and causes of landslides, rock falls, and earth flows.