5.5 GEOLOGY AND SOILS

This section of the Draft Environmental Impact Report (DEIR) evaluates the potential for implementation of the City of Torrance General Plan update to impact geological and soil resources in the City of Torrance. The analysis in this section is based in part on the following technical report(s):

- *Technical Background Report to the Safety Element of the General Plan for the City of Torrance, Los Angeles County, California*, Earth Consultants International, August 2005.

A complete copy of this study is included in the Technical Appendices to this Draft EIR (Volume II, Appendix G)

5.5.1 Environmental Setting

Regulatory Setting

Alquist-Priolo Earthquake Fault Zoning Act

The primary purpose of the act is to mitigate the hazard of fault rupture by prohibiting the location of structures for human occupancy across the trace of an active fault. The act dictates that cities and counties withhold development permits for sites within an earthquake fault zone, as designated by the State Geologist, until geologic investigations demonstrate that the sites are not threatened by surface displacements from future faulting. Projects under this act include all land divisions and most structures for human occupancy. State law exempts single-family wood-frame and steel-frame dwellings that are less than three stories and are not part of a development of four units or more. Earthquake fault zones are along faults that are “sufficiently active” and “well defined.” These faults show evidence of Holocene surface displacement along one or more or their segments (sufficiently active) and are clearly detectable by a trained geologist as a physical feature at or just below the ground surface (well defined). The boundary of an earthquake fault zone is generally about 500 feet from major active faults, and 200 to 300 feet from well-defined minor faults.

Seismic Hazards Mapping Act (SHMA)

Addresses nonsurface fault rupture earthquake hazards, including strong ground shaking, liquefaction, and seismically induced landslides. The California Geological Survey (CGS) is the principal state agency charged with implementing the act. Pursuant to the SHMA, the CGS is directed to provide local governments with seismic-hazard zone maps that identify areas susceptible to liquefaction, earthquake-induced landslides, and other ground failures. The goal is to minimize loss of life and property by identifying and mitigating seismic hazards. The seismic-hazard zones delineated by the CGS are referred to as “zones of required investigation.” Site-specific geological hazard investigations are required by the SHMA when construction projects fall within these areas. The CGS, pursuant to the 1990 SHMA, has been releasing seismic hazard maps since 1997. CGS has completed mapping in the Torrance area under the Seismic Hazards Mapping Act.

Natural Hazards Disclosure Act

Requires that sellers of real property and their agents provide prospective buyers with a “Natural Hazard Disclosure Statement” when the property being sold lies within one or more state-mapped hazard areas. If a property is located in a Seismic Hazard Zone as shown on a map issued by the State Geologist, the seller or the seller’s agent must disclose this fact to potential buyers. California state law also requires that when houses built before 1960 are sold, the seller must give the buyer a completed earthquake hazards disclosure report and a copy of the booklet titled "The Homeowner's Guide to Earthquake Safety." This publication was written and adopted by the California Seismic Safety Commission.

Uniform Building Code (UBC) and California Building Code (CBC)

Current law states that every local agency enforcing building regulations, such as cities and counties, must adopt the provisions of the CBC within 180 days of its publication. The publication date of the CBC is established by the California Building Standards Commission and the code is known as Title 24 of the California Code of Regulations. The most recent building standard adopted by the legislature and used throughout the state is the 2007 version of the CBC, often with local, more restrictive amendments that are based upon local geographic, topographic, or climatic conditions. These building codes are the minimum requirements, and in some cases these requirements may not be adequate to protect health and safety, particularly in the area of faulting and seismology, where the pool of knowledge is rapidly growing and evolving. The CBC is adopted by Torrance in the Municipal Code through Ordinances O-3362, O-3427, O-3469, O-3523, and O-3704 (City of Torrance Municipal Code Division 8, Chapter 1, Article 1, California Building Code).

Unreinforced Masonry Law

The Unreinforced Masonry Law (Section 8875 et seq. of the California Government Code) required all cities and counties in Seismic Zone 4 (zones near historically active faults) to identify potentially hazardous URM buildings in their jurisdictions, establish a URM loss-reduction program, and report their progress to the state by 1990.

Regional Setting

Geomorphic Provinces

California is divided into "geomorphic provinces," which are distinctive, generally easy- to- recognize natural regions in which the geologic record, types of landforms, pattern of landscape features, and climate are similar. The City of Torrance 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 the Los Angeles Basin to the Mexican border.

The Palos Verdes Hills are the westernmost onshore uplift in the Peninsular Ranges province (Catalina Island is an example of an offshore uplift). The hills are geologically complex, the sedimentary rock layers having been folded and faulted into a dome-like structure with the north and south limbs dipping downward from the center of the hill. This structure is complicated locally by smaller-scale folding and faulting. Near the City's southern boundary, the rock is tilted to the north and northeast, generally in the range of about 15 to 45 degrees. At the base of the hills, within City limits, the major structural feature is the northwest-trending Palos Verdes fault zone, which is continuous for about 60 miles, mostly offshore. This fault zone is a steeply dipping oblique-slip fault, and although it has not been zoned by the state under the provisions of the Alquist-Priolo Earthquake Fault Zone Act, the fault is considered by researchers to be an active structure, capable of producing moderate earthquakes.

The Los Angeles coastal plain is underlain by a sequence of marine and nonmarine sediments that are locally more than 30,000 feet thick. Whereas many of the older sediments have proven to be rich in petroleum, younger sediments, deposited primarily by flooding of ancestral rivers, are water bearing, initially providing water for agriculture, and then, in the last century, for urbanization. Torrance overlies the West Coast Groundwater Basin, where the thickness of unconsolidated to semiconsolidated water-bearing sediments is on the order of 1,200 feet.

In recent years, scientists have discovered that the northern end of the province, where the Los Angeles metropolitan area is located, is underlain by a series of deep-seated, low-angle thrust faults that do not reach the surface (referred to as "blind thrusts"). Faults of this type are thought to be responsible for uplift of many of the low hills in the Los Angeles Basin, such as the Repetto and Montebello Hills. Previously undetected blind thrust faults were responsible for the magnitude (M) 5.9 Whittier Narrows earthquake in 1987, and the destructive M6.7 Northridge earthquake in 1994. An older blind thrust fault, the Compton Thrust, underlies the Torrance area.

Elevations

During the last 80 years, the City's natural landscape has been largely altered by dense urban development. Lowland portions of the City, including the area of the El Segundo Sand Hills, are now at elevations ranging from about 60 to 100 feet above sea level. The Palos Verdes Hills rise to an elevation of about 1,480 feet; however, the portions of the hills within City limits reach only to about 400 feet above sea level.

Geologic Setting

The general distribution of geologic units that are exposed at the surface is shown on Figure 5.5-1, *Geologic Map*. Geological material in the Torrance area includes:

- ***Artificial Fill.*** There are many deposits of human-made fill throughout the City, including road and bridge embankments, small canyon fills, and grading associated with leveling of the El Segundo Sand Hills. These deposits vary widely in size, age, and composition, and although some may be extensive, most of these areas are not shown on Figure 5.5-1, *Geologic Map*, due to the scale.
- ***Young Surficial Deposits.*** Holocene deposits (sediments that range in age from about 11,000 years ago to the present) in the City generally occupy the low-lying areas, including beaches and stream channels. Being geologically young and subject to active geologic processes, these deposits are typically unconsolidated and have very little, if any, soil development. These young surficial deposits can be subdivided into four main groups, as described below.
    - *Beach Sediments. (Map Symbol: Qs)* Late Holocene beach sand and gravel form a narrow strandline along the western edge of the city, just north of the Palos Verdes Hills. These sediments generally consist of light gray to tan, fine- to coarse-grained sand, but near Malaga Cove, they include deposits of pebbles and cobbles. The beach deposits typically slope gently towards the ocean. Due to their lack of cohesion and sparse vegetation cover, the beach sands are highly vulnerable to erosion. Their permeability is high, and their expansion potential is low.
    - *Young Alluvium*. *(Map Symbol: Qa)* Late Holocene alluvium consists of loamy clays, silty sands, and fine sands filling stream channels and depressions in the Torrance Plain. Such deposits are typically of low density and contain organic debris. Consequently, they are subject to settlement under loading (for example, under fill embankments or buildings),

  erosion, and poor slope stability. Their expansion characteristics can range from low to high, depending on the grain size of the deposit.

  - *Elevated Alluvium. (Map Symbol: Qae)* This unit consists of fine-grained floodplain deposits, mainly sands, silts, and clays of the Torrance Plain, that have been slightly elevated and incised by modern streams. At the surface, these sediments are unconsolidated; below the upper few feet, they are typically dense to very dense. This alluvium is slightly to moderately susceptible to erosion, and moderately to highly expansive.

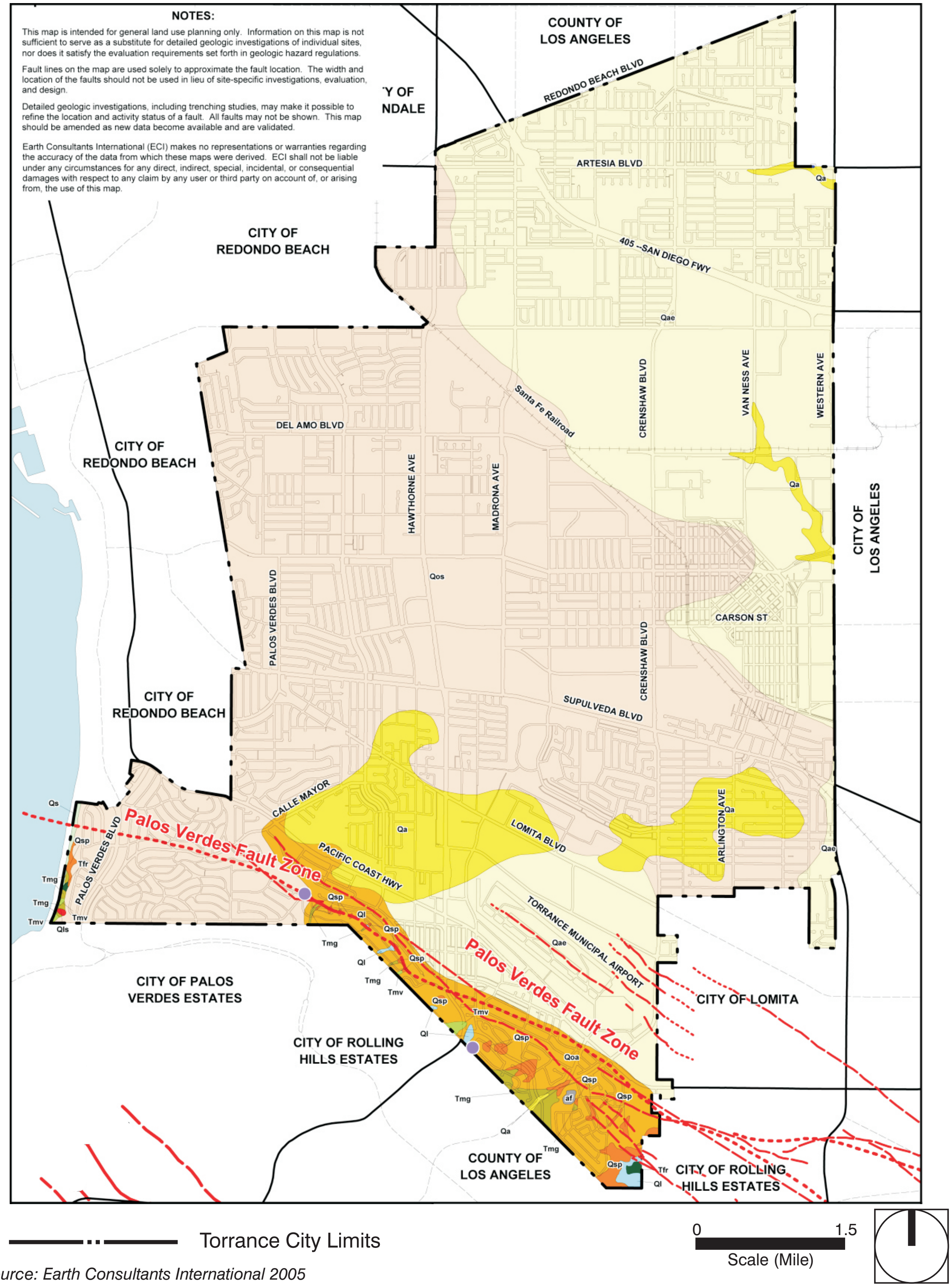
  - *Landslide Deposits. (Map Symbol: Qls)* The occurrence of landslides in Torrance is rare, and most of the significant slope instability in the City is on the steep sea cliff above Torrance Beach and in the flanks of the Palos Verdes Hills. Although only one landslide has been mapped in the sea cliff area (in fact, the only mapped landslide in the City), most of the Torrance sea cliff shows signs of past instability, including slumping, spalling, and soil slippage, as well as erosion. In this area, headward erosion and slope failure may pose a threat to homes at the top of the bluff, particularly those near the edge. Slope instability has also been reported in the southern portion of the City (Torrance 2004) in the Vista Largo – Via Corona area and in the Country Hills area.

- ***Older Surficial Deposits.*** Pleistocene (between about 11,000 and 1.6 million years old) deposits are widespread in the western and central parts of the City, as well as along the north flank of the Palos Verdes Hills. These deposits are unconsolidated to weakly consolidated, and may have moderate to well-developed weathering profiles. Four separate deposits in this age range are recognized in the Torrance area.

  - *Older Alluvium. (Map Symbol: Qoa)* This unit includes sediments eroded from the Palos Verdes Hills and deposited as alluvial fans along the base of the hills. Consisting of sandy loam and loamy clay with lenses of sand and pebble gravel, these sediments are typically dense below the upper few feet. Induration ranges from poor to well developed. Permeability and expansion potential are highly variable, depending on the composition and degree of soil development. Slope stability is generally good. This unit also includes the Palos Verdes Sand, a shallow marine and terrestrial deposit that contains abundant fossils. The thickest section of Palos Verdes sand known in the Palos Verdes peninsula is exposed in the Chandler Quarry just south of the City.

  - *Older Stabilized Dune and Drift Sand. (Map Symbol: Qos)* This unit consists of Late Pleistocene unconsolidated fine- to medium-grained sand, with sandy silt, clay, and gravel near the base. Where deeply weathered and oxidized at the surface, its color typically ranges from yellow to brown; where unweathered, its color ranges from white to gray. These sediments are moderately dense to very dense, but where unweathered (typically starting a few feet below the ground surface) are otherwise similar in characteristics to beach sand deposits. Except where at the soil zone, their expansion potential is low. Due to a lack of cohesion, particularly in the unweathered portion, their erosion potential is high. Most of these deposits are now covered by dense development and their original surfaces and landforms have been altered by grading.

Geologic Map



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.

Fault lines on the map are used solely to approximate the fault location. The width and location of the faults should not be used in lieu of site-specific investigations, evaluation, and design.

Detailed geologic investigations, including trenching studies, may make it possible to refine the location and activity status of a fault. All faults may not be shown. This map should be amended as new data become available and are validated.

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.

Source: Earth Consultants International 2005

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  - *San Pedro Sand. (Map Symbol: Qsp)* The San Pedro sand is mid-Pleistocene in age and consists of dense, weakly consolidated light gray (unweathered) to reddish tan (weathered) sand and pebble gravel with interbedded sandy silt. Bedding ranges from massive to well stratified and locally crossbedded. Sand intervals within this unit are susceptible to erosion, have relatively high permeability, poor surficial slope stability, and a low potential for expansion. Fine-grained intervals are more resistant to erosion, have low permeability, and may be expansive. The San Pedro Sand has been folded and faulted; where bedding planes dip flatter than the slope face, there is a potential for slope instability.

  - *Lomita Marl. (Map Symbol: Ql)* The Lomita marl is mid-Pleistocene in age and stratigraphically underlies the San Pedro *s*and. This unit consists of fossiliferous grayish-white marl (a mix of calcite and grained sediments) and calcareous fine-grained sandstone, with gravel and gray siltstone. The Lomita marl sediments are dense to very dense.

- **Tertiary Sedimentary Rocks.** The Palos Verdes Hills are underlain primarily by an assemblage of sedimentary rocks uplifted by multiple episodes of faulting and folding. All of these rocks are marine in origin, having formed from sediments deposited in a deep ocean embayment that encroached into the Los Angeles basin prior to uplift of the region. These sedimentary deposits are described further below.

  - *Fernando Formation. (Map Symbol: Tfr)* Small, isolated patches of the early Pliocene (about 5 to 10 million years old), Fernando formation are exposed near the base of the Palos Verdes Hills, where it consists of gray, semiconsolidated siltstone to claystone. Bedding in the Fernando formation is generally poorly developed or massive. From an engineering viewpoint, this formation is not compressible, has relatively good gross slope stability, but poor surficial stability, is susceptible to erosion, and is moderately to highly expansive. The units described below are part of the Miocene-age (10 to 26 million years old) Monterey formation. The Monterey formation is widely exposed in the Palos Verdes Hills south of the Palos Verdes fault zone. It also underlies Pleistocene and Holocene deposits that cap the coastal plain, and is exposed in bluffs along the beach. The Monterey Formation consists predominantly of thinly bedded to laminated siliceous siltstone, diatomaceous shale, and clayey siltstone with interbeds of clayey, diatomaceous siltstone and very fine-grained sandstone and diatomite. Locally it contains irregular lenses and thin beds of water-laid tuff (volcanic ash) that is frequently altered to highly plastic clay.

  - *Monterey Formation–Malaga Mudstone Member. (Map Symbol: Tmg)* The late Miocene Malaga Mudstone consists of light gray sandstone and dark grayish brown mudstone with interbedded diatomaceous layers and limestone concretions. Permeability of the rock is low, and its expansion potential is high to very high. Although somewhat resistant to erosion, slope stability of this member is generally poor.

  - *Monterey Formation–Valmonte Diatomite Member. (Map Symbol: Tmv)* The Valmonte Diatomite is a distinctive unit within the Monterey Formation that consists of white, laminated diatomaceous mudstone and shale. This unit is highly porous, but with low permeability, has poor slope stability, is highly expansive, and is not suitable for fill material.

Geologic Hazards

Geologic hazards are generally defined as surficial earth processes that have the potential to cause loss or harm to the community or the environment. The basic elements involved in the assessment of geologic hazards are climate, geology, soils, topography, and land use.

Slope Failure (Landslides)

In Torrance, the hazard of slope instability is a concern due to the occurrence of hillsides within and immediately adjacent to the City. Significantly high and steep slope areas are present along sea cliffs and at the base of the Palos Verdes Hills, and smaller slopes are present in the western part of the City. Although only one landslide has been mapped in the sea cliff above Malaga Cove, slope instability, primarily in the form of soil slips and mudflows, is possible in this area. Similarly, in the northern flank of the Palos Verdes Hills, in the southern part of Torrance, surficial slope instability issues have been reported in the past. For example, in April 1986, there was a major landslide in the Vista Largo–Via Corona area that impacted two houses. The slope was repaired but the houses had to be demolished. Then, in February 1998, a major landslide occurred in the backyards of 24 single-home residential properties on Carolwood Lane and Singingwood Drive. Repair of the hillside was underway as of 2004 (Torrance 2004), with repairs being done for 15 of the 24 impacted properties. Although an active slope failure tends to affect a relatively small area (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.

Careful land management in hillside areas can reduce the risk of economic and social losses from slope failures. This generally includes land use zoning to restrict development in unstable areas, grading codes for earthwork construction, geologic and soil engineering investigation and review, construction of drainage structures, and where warranted, placement of warning systems. Other important factors are risk assessments (including susceptibility maps), a concerned local government, and an educated public.

Slope failures occur in a variety of forms, and there is a distinction made between gross failures and surficial failure. Gross failures include deep–seated or relatively thick side masses, such as landslides, whereas surficial failures can range from minor soil slips to destructive debris flows.

Gross Instability–Landslides. Landslides are movements of relatively large land masses, either as a nearly intact bedrock blocks, or as jumbled mixes of bedrock blocks, fragments, debris, and soils. The type of movement is generally described as translational (slippage on a relatively planar, dipping layer), rotational (circular-shaped failure plane), or wedge (movement of a wedge-shaped block from between intersecting planes of weakness, such as fractures, faults, and bedding). The potential for slope failure is dependent on many factors and their interrelationships. Some of the most important factors include slope height, slope steepness, shear strength, and orientation of weak layers in the underlying geologic unit, as well as poor water pressures. Joints and shears, which weaken the rock fabric, allow penetration of water, leading to deeper weathering of the rock along with increasing the pore pressures, increasing the plasticity of weak clays and 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 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 roadways, are often allowed, at the discretion of the local reviewing agency, 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.

Surficial Instability. Surficial slumps are small slope failures that are relatively common in hillside areas, typically occurring during winters of particularly heavy and prolonged rainfall. Some of the most common types of surficial slope failure are discussed below.

> ***Slope Creep.*** Slope creep is the deformation and movement of the outer soil or rock materials in the face of the slope due to the forces of gravity overcoming the shear strength of the material. Creep occurs most often in soils that develop on fine-grained bedrock units. While soil creep is not catastrophic, it can cause damage to structures and improvements at the tops of slopes.
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> ***Soil Slip.*** Soil slip is generated by strong winter storms, and is widespread in the steeper slope areas, particularly after winters with prolonged and/or heavy rainfall. Failure occurs on canyon side slopes, and in soils that have accumulated in swales, gullies, and ravines. Slope steepness has a strong influence on the development of soil slips, with most slips occurring on slopes with gradients of between about 27 and 56 degrees. In a study of the Santa Paula area of Ventura County, it was found that about 70 percent of the debris flows generated during winter storms occurred on slopes between 20 and 36 degrees. Recent soil slippage has been recorded in Torrance on the steep slopes of an abandoned quarry pit at the base of the Palos Verdes Hills.
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> ***Earth Flow.*** This type of slope failure is a persistent, slow-moving, lobe-shaped slump that typically comes to rest on the slope not far below the failure point. Earth flows commonly form in fine-grained soils (clay, silt, and fine sand), and are mobilized by an increase in pore water pressure caused by infiltration of water during and after winter rains. Earth flows occur on moderate to steep slopes, typically in the range of about 15 to 35 degrees.
>
> ***Debris Flow.*** Debris flow is the most dangerous and destructive of all types of slope failure. A debris flow (also called mudflow, mudslide, and debris avalanche) is 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 speeds as fast as 40 feet per second, is capable of crushing buildings, and can strike with very little warning. As with soil slips, 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. The velocity of the flow depends on the viscosity, slope gradient, height of the slope, roughness and gradient of the channel, and the baffling effects of vegetation.
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> ***Rockfalls.*** Rockfalls are free-falling to tumbling masses of bedrock and soil that have broken off steep canyon walls or cliffs. The debris from repeated rockfalls typically collects at the base of extremely steep slopes in cone-shaped accumulations of angular rock fragments called talus. Rockfalls can happen wherever fractured rock slopes are oversteepened by stream erosion, wave erosion along sea cliffs, or human activities.

Soil Compressibility

Compressible soils are typically geologically young (Holocene in age) unconsolidated sediments of low density that may compress under the weight of proposed fill embankments and structures. The settlement potential and the rate of settlement in these sediments can vary greatly, depending on the soil characteristics (texture and grain size), natural moisture and density, thickness of the compressible layer(s), the weight of the proposed load, the rate at which the load is applied, and drainage. Areas of the City where compressible soils are most likely to occur are the active and recently active stream channels, beach deposits, and young alluvial fan deposits. Deep fill embankments, generally those in excess of about 60 feet deep, will also compress under their own weight. Areas covered with unengineered artificial fill may also be susceptible to this hazard. In the Palos Verdes Hills, compressible soils are commonly found in canyon bottoms, swales, and at the base of natural slopes.

Soil Collapse

Hydroconsolidation or soil collapse typically occurs in recently deposited Holocene soils that accumulated in an arid or semiarid environment. Soils prone to collapse are also commonly associated with wind-deposited sands and silts, and alluvial fan and debris flow sediments deposited during flash floods. These soils are typically dry and contain minute pores and voids. The soil particles may be partially supported by clay, silt, or carbonate bonds. When saturated, collapsible soils undergo a rearrangement of their grains and a loss of cementation, resulting in substantial and rapid settlement under relatively light loads. An increase in surface water infiltration, such as from irrigation, or a rise in the groundwater table, combined with the weight of a building or structure, can initiate rapid settlement and cause foundations and walls to crack. Typically, differential settlement of structures occurs when landscaping is heavily irrigated in close proximity to the structure's foundation.

Most of the sediments that underlie the Torrance area are generally not susceptible to this hazard due to their age and density. However, localized areas, such as recently active drainage channels and deposits of younger alluvium in the southern part of the City could meet the conditions needed for collapse to occur.

Expansive Soils

Fine-grained soils, such as silts and clays, may contain variable amounts of expansive clay minerals. These minerals can undergo significant volumetric changes as a result of changes in moisture content. The upward pressures induced by the swelling of expansive soils can have significant harmful effects upon structures and other surface improvements.

The northeastern and southern parts of the City are underlain by fine-grained flood-plain sediments that are composed primarily of silty sand with variable amounts of clay. Sediments of this type are typically in the moderate range for expansion potential, and may be locally in the high range, depending on the clay content. Expansive soils are specifically known to occur in the area around Ocean Avenue and Lomita Boulevard, where continuous fixing of the roadways is required due to damage caused by shrinking and swelling of the underlying materials. Soils developed on the older surficial deposits, such as older alluvium, are commonly clay-rich and will probably fall in the moderately expansive range. Bedrock of the Monterey formation, as well as silty intervals in the San Pedro sand, may also be in the moderate to high range. Topsoils developed on fine-grained bedrock units will also be moderately to highly expansive. Areas underlain by beach and dune sands have very little expansion potential. In some cases, engineered fills may be expansive and cause damage to improvements if such soils are incorporated into the fill near the finished surface.

Ground Subsidence

Ground subsidence is the gradual settling or sinking of the ground surface with little or no horizontal movement. Most ground subsidence is human induced. In the areas of southern California where significant ground subsidence has been reported (such as Antelope Valley, Murrieta, and Wilmington) this phenomenon is usually associated with the extraction of oil, gas, or groundwater from below the ground surface in valleys filled with recent alluvium.

Ground-surface effects related to regional subsidence can include earth fissures, sinkholes or depressions, and disruption of surface drainage. Damage is generally restricted to structures sensitive to slight changes in elevations, such as canals, levees, underground pipelines, and drainage courses; however, significant subsidence can result in damage to wells, buildings, roads, railroads, and other improvements. Subsidence has largely been brought under control in affected areas by good management of local water supplies, including reducing pumping of local wells, importing water, and use of artificial recharge.

No regional subsidence as a result of groundwater pumping has been reported or noted in the Torrance area. The West Coast Groundwater Basin, which underlies the City, is managed by the Water Replenishment District of Southern California. This agency monitors groundwater levels and quality, storing an extensive database of information. Numerous projects and programs through local, state, and federal agencies are currently in progress in the Torrance area to maintain groundwater levels in the West Coast Basin and reduce the dependency on imported water, while still meeting the present and future water needs of a growing population. These projects and programs include water treatment facilities, expansion of water recycling infrastructure, injecting water into the ground, capturing stormwater before it reaches the ocean, spreading captured water for infiltration, preventing seawater intrusion into fresh water aquifers, and a pilot desalinization program.

Subsidence due to oil and gas extraction has been reported in several areas of southern California, including in the Torrance oil field region. Most subsidence associated with this oil field has occurred in the Redondo Beach area, where a bowl-shaped depression is indicated by land surveys conducted between 1978 and 1994. The surveys indicate a subsidence rate of as much as three centimeters per year between 1978 and 1989, and about two millimeters per year between 1989 and 1994. Damage to structures and infrastructure associated with this period of subsidence has not been reported in the Torrance area. More recent surveys appear to indicate that subsidence is no longer occurring in the area, at least at the previous rates. Subsidence due to oil extraction was also reported in the Wilmington oil field, to the east and south of Torrance, where as much as 30 feet of subsidence was reported during the 1940s. To counteract the subsidence, a pilot waterflooding program was begun in 1953; the results of this program showed that subsidence could be effectively stopped and prevented using this technique. Waterflooding also increased oil recoverability; thus, in the early 1960s, the City of Long Beach permitted an increase in oil extraction from its offshore areas.

Erosion

Erosion, runoff, and sedimentation are influenced by several factors, including climate, topography, soil and rock types, and vegetation. Natural erosion processes are often accelerated through human activities. Grading increases the potential for erosion and sedimentation by removing protective vegetation, altering natural drainage patterns, compacting the soil, and constructing cut-and-fill slopes that may be more susceptible to erosion than the natural condition.

Erosion is a significant concern in Torrance, especially along the shoreline, where beach sediments and coastal bluffs are highly susceptible to erosion by wave action. Other parts of the City, including slopes (both natural and human-made) in the Palos Verdes Hills, are also susceptible to the impacts from precipitation, stream erosion, and human activities.

Windblown Sand

Wind erosion is a serious environmental problem attracting the attention of many across the globe. It is a common phenomenon occurring mostly in relatively flat, bare areas; dry, sandy soils; or anywhere the soil is loose, dry, and finely granulated. Wind erosion damages land and natural vegetation by removing soil from one place and depositing it in another. It causes soil loss, dryness and deterioration of soil structure, nutrient and productivity losses, air pollution, and sediment transport and deposition.

Soil movement is initiated by wind against the ground surface. For each specific soil type and surface condition, there is a minimum velocity required to move soil particles. This is called the threshold velocity. Once this velocity is reached, the quantity of soil moved is dependent upon the particle size, the cloddiness of particles, and wind velocity itself. Suspension, saltation, and surface creep are the three types of soil movement that occur during wind erosion. While soil can be blown away at virtually any height, the majority (over 93 percent) of soil movement takes place at or within about three feet of the ground surface.

Wind-blown sand was a major concern in the Torrance area when the City was first established. The westerly winds, which in the summer keep the temperature in Torrance ten degrees cooler than neighboring Los Angeles, used to pick up large amounts of sand from undeveloped properties, and this wind-borne sand would impact the equipment of many of Torrance's founding industries. At Union Tool, this sand required an unusual amount of maintenance of the machine tools to keep them running. Now that the area is mostly developed, covered in hardscape and landscaping vegetation, wind-blown sand no longer poses a hazard.

Seismic Hazards

Although faults exist everywhere, most earthquakes occur on or near plate boundaries. Thus, southern California has many earthquakes, because it straddles the boundary between the North American and Pacific plates, and fault rupture accommodates their motion. Torrance is riding on the Pacific plate, which is moving northwesterly (relative to the North American plate), at about 50 millimeters per year. At this rate, Torrance will be hundreds of kilometers north of San Francisco in 15 million years.

When comparing the sizes of earthquakes, the most meaningful feature is the amount of energy released. Thus scientists most often consider seismic moment, a measure of the energy released when a fault ruptures. We are more familiar, however, with scales of magnitude, which measure amplitude of ground motion. Magnitude scales are logarithmic. Each one-point increase in magnitude represents a 10-fold increase in amplitude of the waves as measured at a specific location, and a 32-fold increase in energy. That is, a magnitude 7 earthquake produces 100 times (10 × 10) the ground motion amplitude of a magnitude 5 earthquake. Another measure of earthquake size used is the seismic intensity scale, which is a qualitative assessment of an earthquake's effects at a given location. The most commonly used measure of seismic intensity is called the Modified Mercalli Intensity (MMI) scale, which has 12 damage levels and is shown in Table 5.6-1. A given earthquake will have one moment and, in principle, one magnitude, although there are several methods of calculating magnitude that give slightly different results. However, one earthquake will produce many levels of intensity because intensity effects vary with the location and the perceptions of the observer.

Table 5.5-1
Abridged Modified Mercalli Intensity Scale

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

Source: ECI Report, August 2005.

The bigger and closer the earthquake, the greater the damage it may generate. Thus fault dimensions and proximity are key parameters in any hazard assessment. In addition, it is important to know a fault's style of movement, the age of its most recent activity, its total displacement, and its slip rate (all discussed below). These values allow an estimation of how often a fault produces damaging earthquakes, and how big an earthquake should be expected the next time the fault ruptures.

The State of California, under the guidelines of the Alquist-Priolo Earthquake Fault Zoning Act of 1972, classifies faults according to the following criteria:

- ***Active:*** faults showing proven displacement of the ground surface within about the last 11,000 years (within the Holocene Epoch) that are thought capable of producing earthquakes
- ***Potentially Active:*** faults showing evidence of movement within the last 1.6 million years, but that have not been shown conclusively to have moved in the last 11,000 years
- ***Not Active:*** faults that have conclusively not moved in the last 11,000 years.

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

Surface (Fault) Rupture

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

Strong Seismic Ground Shaking

Strong ground shaking causes the vast majority of earthquake damage. Horizontal ground acceleration is frequently responsible for widespread damage to structures, so it is commonly estimated as a percentage of g, the acceleration of gravity. Full characterization of shaking potential, though, requires estimates of peak ground displacement and velocity, the duration of strong shaking, and the lengths of waves that will control each of these factors at a given location. We look to the recorded effects of damaging earthquakes worldwide to understand what might happen in similar environments here in the future.

Based on the deterministic ground shaking analysis performed for Torrance, these faults that can cause peak horizontal ground acceleration of about 0.1g or greater (MMIs greater than about VII) are listed in Table 5.6-2.

Table 5.5-2
Estimated Horizontal Peak Ground Accelerations and Seismic Intensities in the Torrance Area

Fault Name	Distance to Torrance (miles)	Magnitude of M_{max}	PGA (g) from M_{max}	MMI from M_{max}
Palos Verdes	0–6.6	7.3	1.1–0.6	XII–X
Puente Hills Blind Thrust	0.5–6.2	7.1	1.3–0.6	XII–X
Puente Hills (Coyote Hills segment)	0.5–6.2	6.6	1.3–0.5	XII–X
Puente Hills (Los Angeles segment)	8.3–15	6.6	0.3–0.15	IX–VIII
Puente Hills (Santa Fe Springs)	10–16	6.5	0.3–0.13	IX–VIII
Newport-Inglewood (Onshore)	3–10	7.1	0.6–0.3	X–IX
Elysian Park Thrust	10–19	6.7	0.3–0.12	IX–VIII
Santa Monica	15–19	6.6	0.15–0.11	VIII–VII
Malibu Coast	16–20	6.7	0.13–0.11	VIII–VII
Hollywood	16–20	6.4	0.13–0.09	VIII–VII
Upper Elysian Park	12–19	6.4	0.18–0.12	VIII–VII
Anacapa-Dume	23–26	7.5	0.15–0.12	VIII–VII
Whittier	18–25	6.8	0.12–0.08	VII
Raymond	18–24	6.5	0.11–0.07	VII–VI
Verdugo	21–28	6.9	0.11–0.08	VII
San Andreas-1857 Rupture	47–54	7.8	0.08–0.07	VII–VI

Source: ECI Report, September 2005.

M_{max}: Maximum magnitude of earthquake; the acceleration of gravity; PGA: peak ground acceleration as a percentage of g; MMI: Modified Mercalli Intensity.

Notable earthquakes within the Torrance Area, in chronological order:

- **Unnamed Earthquake of 1796.** An estimated magnitude of at least 6 has been assigned to the event based on the explorers' account. Recent studies of coastal uplift attributed to the earthquake suggest it may have had a magnitude as high as 7.3 and occurred on a blind fault beneath the San Joaquin Hills. The nearby Elsinore and Newport-Inglewood faults are also considered possible sources for the earthquake.

- **Unnamed Earthquake of 1800.** An earthquake with an estimated magnitude of 6.5 occurred on November 22 in the coastal region of southern California. Based on the distribution of damage attributed to the earthquake, the epicenter is thought to have been between Newport Beach and San Diego, and was possibly offshore. The earthquake damaged the mission at San Juan Capistrano and collapsed a barracks in the present-day Old Town district of San Diego (The Virtual Museum of the City of San Francisco 2009).

- **Wrightwood Earthquake of December 12, 1812.** Based on accounts of damage recorded at missions in the earthquake-affected area, an estimated magnitude of 7.5 has been calculated for the event. Subsurface investigations and tree-ring studies show that the earthquake likely ruptured the Mojave Section of the San Andreas fault near Wrightwood, and may have been accompanied by a significant surface rupture between Cajon Pass and Tejon Pass.

- **Unnamed Earthquake of December 21, 1812.** The Wrightwood earthquake was followed by a strong earthquake on December 21 that caused widespread damage in the Santa Barbara area. The effects of this second earthquake are sometimes attributed to the December 12 event, giving the impression that a single large earthquake caused significant damage from Santa Barbara to San Diego. The second earthquake had an estimated magnitude of 7 and was likely offshore in the Santa Barbara Channel, although it could have occurred inland in Santa Barbara or Ventura Counties (Southern California Earthquake Data Center 2005).

- **Unnamed Earthquake of 1855.** This earthquake occurred on July 11and was felt across southern California from Santa Barbara to San Bernardino.
- **Elsinore Earthquake of 1910.** This magnitude 6 earthquake occurred on May 15, at 7:47 AM Pacific Standard Time (PST), following two moderate tremors that occurred on April 10 and May 12.The Elsinore fault is thought to have caused the earthquake, although no surface rupture along this fault was reported.
- **San Jacinto Earthquake of 1918.** This magnitude 6.8 earthquake occurred on April 21 near the town of San Jacinto.
- **Long Beach Earthquake of 1933.** The Long Beach earthquake occurred on March 10 following a strong foreshock the day before. The earthquake ruptured the Newport-Inglewood fault and was felt from the San Joaquin valley to Northern Baja.
- **Torrance-Gardena Earthquakes of 1941.** Two small earthquakes struck the southern Los Angeles basin, affecting surrounding communities. Although these earthquakes were relatively minor, they occurred close to the surface and caused significant, although local damage. The magnitude 4.8 Torrance earthquake occurred on October 21. A second earthquake occurred less than a month later, on November 14 at 12:42 AM PST, near Wilmington. Shaking during the second earthquake was reportedly stronger than the first, locally reaching intensity level VIII and felt as far away as Cabazon, Carpinteria, and San Diego.
- **San Jacinto Fault Earthquake of 1954.** Also known as the Arroyo Salada earthquake, this magnitude 6.4 earthquake struck on March 19. The Clark fault of the San Jacinto fault zone may have been involved.
- **Borrego Mountain Earthquake of 1968.** This magnitude 6.5 earthquake struck on April 8. It resulted in about 18 miles of surface rupture along the Coyote Creek Fault (a branch of the San Jacinto fault zone), and triggered slip was observed on fault systems up to 40 miles away.
- **San Fernando (Sylmar) Earthquake of 1971.** This magnitude 6.6 earthquake occurred on the San Fernando fault zone, the westernmost segment of the Sierra Madre fault, on February 9. The surface rupture caused by this earthquake was nearly 12 miles long, and occurred in the Sylmar-San Fernando area.
- **Oceanside Earthquake of 1986.** This magnitude 5.4 earthquake occurred on the morning of July 13 at 6:47 AM Pacific Daylight Time. The epicenter was about 32 miles offshore from Oceanside on an unidentified fault that may be related to the San Diego Trough or the Palos Verdes-Coronado Bank fault zones (Southern California Earthquake Data Center 2005).
- **Whittier Narrows Earthquake of 1987.** The Whittier Narrows earthquake occurred on October 1, at 7:42 in the morning local time, with its epicenter approximately 21 miles northeast of Torrance. This

magnitude 5.9 earthquake occurred on a previously unknown, north-dipping concealed thrust fault (blind thrust) now called the Puente Hills fault.

- **Landers Earthquake of 1992.** This magnitude 7.3 earthquake occurred on June 28 and was the largest earthquake to hit California in 40 years. The earthquake was centered approximately 120 miles from Los Angeles, in the small desert community of Landers. More than 50 miles of surface rupture associated with five or more faults occurred as a result of this earthquake.

- **Northridge Earthquake of 1994.** On the morning of January 17, at 4:31, a M 6.7 earthquake struck the San Fernando Valley. This moderate-sized tremor was the most expensive earthquake in United States history, due primarily to its proximity to the heavily populated northern Los Angeles area. The rupture occurred in the San Fernando Valley on the previously unidentified eastern continuation of the Oak Ridge fault, a blind thrust fault.

- **Hector Mine Earthquake of 1999.** This magnitude 7.1 quake occurred on October 18 in a remote region of the Mojave Desert, 47 miles east-southeast of Barstow. MMIs of IV were reported in the Torrance area.

Seismically Induced Slope Failure

Strong ground motion can worsen existing unstable slope conditions, particularly if coupled with saturated ground conditions. Seismically induced landslides can overrun structures, people, or property; sever utility lines; and block roads, thereby hindering rescue operations after an earthquake. Over 11,000 landslides were mapped shortly after the 1994 Northridge earthquake, all within a 45-mile radius of the epicenter. Although numerous types of earthquake-induced landslides have been identified, the most widespread type generally consists of shallow failures involving surficial soils and the uppermost weathered bedrock in moderate to steep hillside terrain (these are also called disrupted soil slides). Rock falls and rock slides on very steep slopes are also common. The 1989 Loma Prieta and Northridge earthquakes showed that reactivation of existing deep-seated landslides also occurs. Numerous landslides have been mapped in the San Joaquin Hills in eastern Newport Beach.

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

A few steep slopes along the southern and southwestern parts of Torrance have been mapped as vulnerable to seismically induced slope failure. Some of these are areas where slope instability has been reported in the past. The past occurrence of landslides in some of these areas indicates that without mitigation, slope instability can pose a significant hazard to developments in these areas. Rupture along the Palos Verdes fault could also reactivate existing landslides and cause new slope failures throughout the Palos Verdes Hills. Slope failures can also be expected to occur along stream banks, steep earthen reservoir or debris basin walls, and coastal bluffs.

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

Liquefaction and Related Ground Failure

Liquefaction is a process whereby strong earthquake shaking causes sediment layers that are saturated with groundwater to lose strength and behave as a fluid. This subsurface process can lead to near-surface or surface ground failure that can result in property damage and structural failure. If surface ground failure does occur, it is usually expressed as lateral spreading, flow failures, ground oscillation, and/or general loss of bearing strength. Sand boils can commonly accompany these different types of failure.

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

When soils liquefy, the structures built on them can sink, tilt, and suffer significant structural damage. Liquefaction-related effects include loss of bearing strength, ground oscillations, lateral spreading, and flow failures or slumping. The excess water pressure is relieved by the ejection of material upward through fissures and cracks. A water-soil slurry bubbles onto the ground surface, resulting in features called “sand boils,” “sand blows,” or “sand volcanoes.”

In order to determine a region’s susceptibility to liquefaction, three major factors must be analyzed. These include:

- The intensity and duration of ground shaking.
- The age and textural characteristic of the alluvial sediments: Generally, the younger, less well compacted sediments tend to have a higher susceptibility to liquefaction. Textural characteristics also play a dominant role in determining liquefaction susceptibility. Sand and silty sands deposited in river channels and floodplains tend to be more susceptible to liquefaction and floodplains tend to be more susceptible to liquefaction than coarser or finer grained alluvial materials.
- The depth to the groundwater: Groundwater saturation of sediments is required in order for earthquake-induced liquefaction to occur. In general, groundwater depths shallower than 10 feet to the surface can cause the highest liquefaction susceptibility.

There are three general conditions that need to be met for liquefaction to occur. The first of these—strong ground shaking of relatively long duration—can be expected to occur in the Torrance area as a result of an earthquake on any of several active faults in the region. The second condition—unconsolidated granular sediments—occurs in scattered areas in Torrance, two of which are irregularly shaped areas to the west and north. The third condition—water-saturated sediments within about 50 feet of the surface—occurs only along the old, natural channel of Dominguez Creek and at the beach.

Research and historical data indicate that loose, granular materials at depths of less than 50 feet with silt and clay contents of less than 30 percent saturated by relatively shallow groundwater table are most susceptible to liquefaction. These geological conditions are typical in parts of southern California, including the City of Torrance, and in valley regions and alluviated floodplains. The types of ground failure typically associated with liquefaction are explained below.

- **Lateral spreading.** Lateral displacement of surficial blocks of soil as the result of liquefaction in a subsurface layer is called lateral spreading. Once liquefaction transforms the subsurface layer into a fluid-like mass, gravity plus inertial forces caused by the earthquake may move the mass downslope toward a cut slope or free face (such as a river channel or a canal). Lateral spreading most commonly occurs on gentle slopes that range between 0.3 and 3 degrees, and can displace the ground surface by several to tens of meters. Such movement damages pipelines, utilities, bridges, roads, and other structures.

- **Flow failure.** The most catastrophic mode of ground failure caused by liquefaction is flow failure. Flow failure usually occurs on slopes greater than three degrees. Flows are principally liquefied soil or blocks of intact material riding on a liquefied subsurface.

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

- **Loss of bearing strength.** When a soil liquefies, loss of bearing strength may occur beneath a structure, possibly causing the building to settle and tip. If the structure is buoyant, it may float upward.

- **Ground lurching.** Soft, saturated soils have been observed to move in a wavelike manner in response to intense seismic ground shaking, forming ridges or cracks on the ground surface. Areas underlain by thick accumulation of colluvium and alluvium appear to be the most susceptible to ground lurching. Under strong ground-motion conditions, lurching can be expected in loose, cohesionless soils, or in clay-rich soils with high moisture content. In some cases, the deformation remains after the shaking stops.

Hazardous Buildings (Unreinforced Masonry)

The principal threat in an earthquake is not limited to ground shaking, fault rupture or liquefaction, but the damage that the earthquake causes to buildings that house people or an essential function. Continuing advances in engineering design and building code standards over the past decade have greatly reduced the potential for collapse in an earthquake of most of our new buildings. However, many buildings were built before some of the earthquake design standards were incorporated into the building code. Several specific building types are a particular concern in this regard.

- ***Unreinforced Masonry Buildings:*** In the late 1800s and early 1900s, unreinforced masonry was the most common type of construction for larger downtown commercial structures and for multistory apartment and hotel buildings. These were recognized as a collapse hazard following the San Francisco earthquake of 1906, the Santa Barbara earthquake of 1925, and again the aftermath of the Long Beach earthquake of 1933. These buildings are still recognized as the most hazardous buildings in an earthquake.

  Per Senate Bill 547, local jurisdictions are required to enact structural hazard reduction programs by (a) inventorying pre-1943 unreinforced masonry buildings, and (b) developing mitigation programs to correct the structural hazards. In the year 2000, the City reported to the Seismic Safety Commission that there were 50 URMs in Torrance, none of which was considered of historical significance. All of the property owners were notified of the type of construction they owned, and of these, 43 buildings were strengthened to comply with the 1982 edition of Division 88 of the Los Angeles City Code, the City-mandated mitigation standard for URMs. The remaining seven structures were demolished.

- ***Precast Concrete Tilt-up Buildings:*** This building type was introduced following World War II and gained popularity in light industrial buildings during the late 1950s and 1960s. Extensive damage to concrete tilt-up buildings in the 1971 San Fernando earthquake revealed the need for better anchoring of walls to the roof, floor, and foundation elements of the building and for stronger roof diaphragms.[1] In the typical damage to these buildings, the concrete wall panels would fall outward and the adjacent roof would collapse, creating a direct hazard. Collapse of this type of structure generates heavy debris, and removal of this debris requires the use of heavy equipment.

- ***Soft-Story Buildings:*** Soft-story buildings are those in which at least one story, commonly the ground floor, has significantly less rigidity and/or strength than the rest of the structure. This can form a weak link in the structure unless special design features are incorporated to give the building adequate structural integrity. Typical examples of soft-story construction are buildings with glass curtain walls on the first floor only, or buildings placed on stilts or columns, leaving the first story open for landscaping, street-friendly building entry, parking, or other purposes. In the early 1950s to early 1970s, soft-story buildings were a popular construction style for low- and mid-rise concrete frame structures. The City of Torrance should consider conducting an inventory of their soft-stories, and encouraging the structural retrofit of these structures to withstand collapse during an earthquake.

- ***Nonductile Concrete Frame Buildings:*** The brittle behavior of nonductile concrete frame buildings can create major damage and even collapse under strong ground shaking. This type of construction, which generally lacks masonry shear walls, was common in the very early days on reinforced concrete buildings, and they continued to be built until the codes were changed to require ductility in the moment-resisting frame in 1973. There were large numbers of these buildings built for commercial and light industrial use in California's older, densely populated cities. Although many of these buildings have four to eight stories, there are many in the lower height range. This category also includes one-story parking garages with heavy concrete roof systems supported by nonductile concrete columns.

- ***Wood-Frame Structures:*** Structural damage to wood-frame structures often results from an inadequate connection between the superstructure and the foundation. These buildings may slide off their foundations, with consequent damage to plumbing and electrical connections. Unreinforced masonry chimneys may also collapse. These types of damage are generally not life threatening, although they may be costly to repair. Wood-frame buildings with stud walls generally perform well in an earthquake unless they have no foundation or have a weak foundation constructed of unreinforced masonry or poorly reinforced concrete. In these cases, damage is generally limited to cracking of the stucco, which dissipates much of the earthquake's induced energy. The collapse of wood frame structures, if it happens, generally does not generate heavy debris, but rather, the wood and plaster debris can be cut or broken into smaller pieces by hand-held equipment and removed by hand in order to reach victims.

- ***Reinforced Concrete Frame Buildings:*** Reinforced concrete frame buildings, with or without reinforced infill walls, display low ductility. Earthquakes may cause shear failure (if there are large tie spacings in columns, or insufficient shear strength), column failure (due to inadequate rebar splices, inadequate reinforcing of beam-column joints, or insufficient tie anchorage), hinge deformation (due to lack of continuous beam reinforcement), and nonstructural damage (due to the relatively low stiffness of the frame). A common type of failure observed following the Northridge earthquake was

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[1] A roof diaphragm is a structural roof deck that is capable of resisting shear that is produced by lateral forces, such as wind or seismic loads.

confined column collapse, where infilling between columns confined the length of the columns that could move laterally in the earthquake.

- ***Multi-Story Steel Frame Buildings:*** Multistory steel frame buildings generally have concrete floor slabs. However, these buildings are less likely to collapse than concrete structures. Common damage to these types of buildings is generally nonstructural, including collapsed exterior curtain wall (cladding), and damage to interior partitions and equipment. Overall, modern steel frame buildings have been expected to perform well in earthquakes, but the 1994 Northridge earthquake broke many welds in these buildings, a previously unanticipated problem.

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

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

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

5.5.2 Thresholds of Significance

According to Appendix G of the CEQA Guidelines, a project would normally have a significant effect on the environment if the project would:

G-1 Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:

  i) Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault. (Refer to Division of Mines and Geology Special Publication 42.)

  ii) Strong seismic ground shaking.

  iii) Seismic-related ground failure, including liquefaction.

iv) Landslides.

G-2 Result in substantial soil erosion or the loss of topsoil.

G-3 Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse.

G-4 Be located on expansive soil, as defined in Table 18-1B of the Uniform building Code (1994), creating substantial risks to life or property.

G-5 Have soils incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems where sewers are not available for the disposal of waste water.

The Initial Study, included as Appendix A, substantiates that impacts associated with the following thresholds would be less than significant:

- Threshold G-5

This impact will not be addressed in the following analysis.

5.5.3 Environmental Impacts

The following impact analysis addresses thresholds of significance for which the Initial Study disclosed potentially significant impacts. The applicable thresholds are identified in brackets after the impact statement.

IMPACT 5.5-1: BUILDOUT OF THE TORRANCE GENERAL PLAN WOULD EXPOSE RESIDENTS, OCCUPANTS, EMPLOYEES, VISITORS, ETC., TO POTENTIAL SEISMIC-RELATED HAZARDS. [THRESHOLD G-1])

Impact Analysis: The City of Torrance lies in close proximity to several active and potentially active faults, which may result in seismic hazards to structures and persons within Torrance during a seismic event. Although it may be impossible to prevent an earthquake from occurring, its effects can be minimized. Potential seismic hazards in the Torrance area include strong seismic ground shaking, surface-fault rupture, and related ground failure.

Ground Shaking

A probabilistic analysis for City Hall indicates that the Torrance area has a 10 percent probability of experiencing ground motions of between approximately 0.43g (for stiff soils) and 0.52g (for alluvium) in the next 50 years. These probabilistic ground motion values for Torrance are in moderate to high range for southern California, and are the result of the City's proximity to major fault systems with high earthquake recurrence rates. These levels of shaking can be expected to cause damage, particularly to older and poorly constructed buildings. While new construction would be required to adhere to the most recently adopted Uniform Building Code (UBC), the UBC is not retroactive.

Structures built before 1971 are particularly susceptible to damage during an earthquake, including URM structures, precast tilt-up concrete buildings, soft-story structures, unreinforced concrete buildings, and pre-1952 single-family structures. Other potentially hazardous buildings include irregularly shaped structures and mobile homes. In addition to older structures, essential facilities are those parts of a community's infrastructure that must remain operational after an earthquake. Buildings that use essential services include schools, hospitals, fire and police stations, emergency operations centers, and communication centers. It is crucial that essential facilities have no structural weaknesses that can lead to collapse. In Torrance, essential facilities include two hospitals, 30 public schools, six fire stations, and one police station. Therefore, while the earthquake hazard mitigation improvements associated with the current building codes address new construction, the retrofit and strengthening of existing structures requires the adoption of ordinances.

In the year 2000, the City reported to the Seismic Safety Commission that there were 50 URMs in Torrance, none of which were considered of historical significance. All of the property owners were notified of the type of construction they owned, and of these, 43 buildings were strengthened to comply with the 1982 edition of Division 88 of the Los Angeles City Code, the City-mandated mitigation standard for URMs. The remaining7 structures were demolished. Existing ordinances and proposed general plan policies and objectives would further reduce hazards to existing structures.

Rupture

Primary ground rupture due to fault movement typically results in a relatively small percentage of the total damage in an earthquake, yet being too close to a rupturing fault can result in extensive damage. The Palos Verdes Fault is the only known fault with the potential to generate primary surface rupture in the City of Torrance.

Since much of the Palos Verde Fault has already been built upon, there is little that can be done to prevent damage to existing buildings that are on top of or near the fault. Redevelopment of areas near the fault would include studies to determine the exact locations of the fault and its lineaments.

Additionally, a fault hazard management zone has been established around the traces of the Palos Verdes fault that are considered more recently active (green zone in Figure 5.5-2). This fault hazard management zone is asymmetrical, that is, wider on one side of the fault, consistent with observations of past earthquakes that show that there is more surface deformation and damage on the upthrown block (in this case, the south side of the fault).

Landslides

The majority of Torrance is relatively flat and is not at risk for landslides. However, the southern portions of the City near the Palos Verdes Hills are prone to forms of landslides, especially soil slips and mudflows, because of the natural grade. In general, slopes with a grade of 15 percent or more have the greatest potential to cause landslides. These can be induced by either earthquakes or high amounts of precipitation.

Torrance has development restrictions and processes to mitigate landslide risks. For suspect slopes, appropriate geotechnical investigation and slope stability analyses would be performed for both static and dynamic (earthquake) conditions. For deeper slides, mitigation typically includes such measures as buttressing slopes or regrading the slope to a different configuration. Protection from rock falls or surface slides can often be achieved by protective devices such as barriers, retaining structures, catchment areas, or a combination of these. The runout area of the slide at the base of the slope and the potential bouncing of rocks would also be considered prior to development. If it is not feasible to mitigate unstable slope conditions, the City would recommend building setbacks that should be imposed.

The Torrance Municipal Code gives the Building Official the authority to prevent development on sloped areas when "…any existing excavation, embankment, fill, hillside or slope area has become or constitutes a hazard to safety or public welfare, or endangers property, or adversely affects the safety, use or stability *of a public way or drainage course…" (Torrance Municipal Code Section Section 81.2.39, Excavation and Grading). These areas are then identified as hazard areas.*

Overall, the residents and businesses of Torrance are exposed to seismic hazards including groundshaking, fault ruptures, and landslides. Since the City is almost entirely built out, the existing built environment would not be changed significantly as the proposed general plan is built out. New structures would be built to standards enforced by the City to prevent risk to persons and property, improving the safety of the built environment. Hazardous areas, including lots susceptible to landslides and areas within the fault hazard management zones, would follow building and design requirements to improve the safety of these areas.

To reduce the hazards associated with seismic activity, the City requires that all new development abide by the most recently adopted City and state seismic and geotechnical requirements to protect injury and structural damage due to geologic and seismic hazards. Since the amount of new development in the City would not increase substantially upon buildout of the general plan and any new development would be required to follow development restrictions, the impacts related to seismic hazards would be less than significant.

IMPACT 5.5-2: UNSTABLE GEOLOGIC UNITS AND SOILS CONDITIONS, INCLUDING SOIL EROSION, ARE WITHIN THE BOUNDARIES OF THE CITY OF TORRANCE. [THRESHOLDS G-2, G-3, AND G-4]

Impact Analysis: The City of Torrance is in a region with the potential for unstable ground conditions to occur, including unstable slopes, compressible soils, expansive soils, and ground subsidence.

Slope Instability

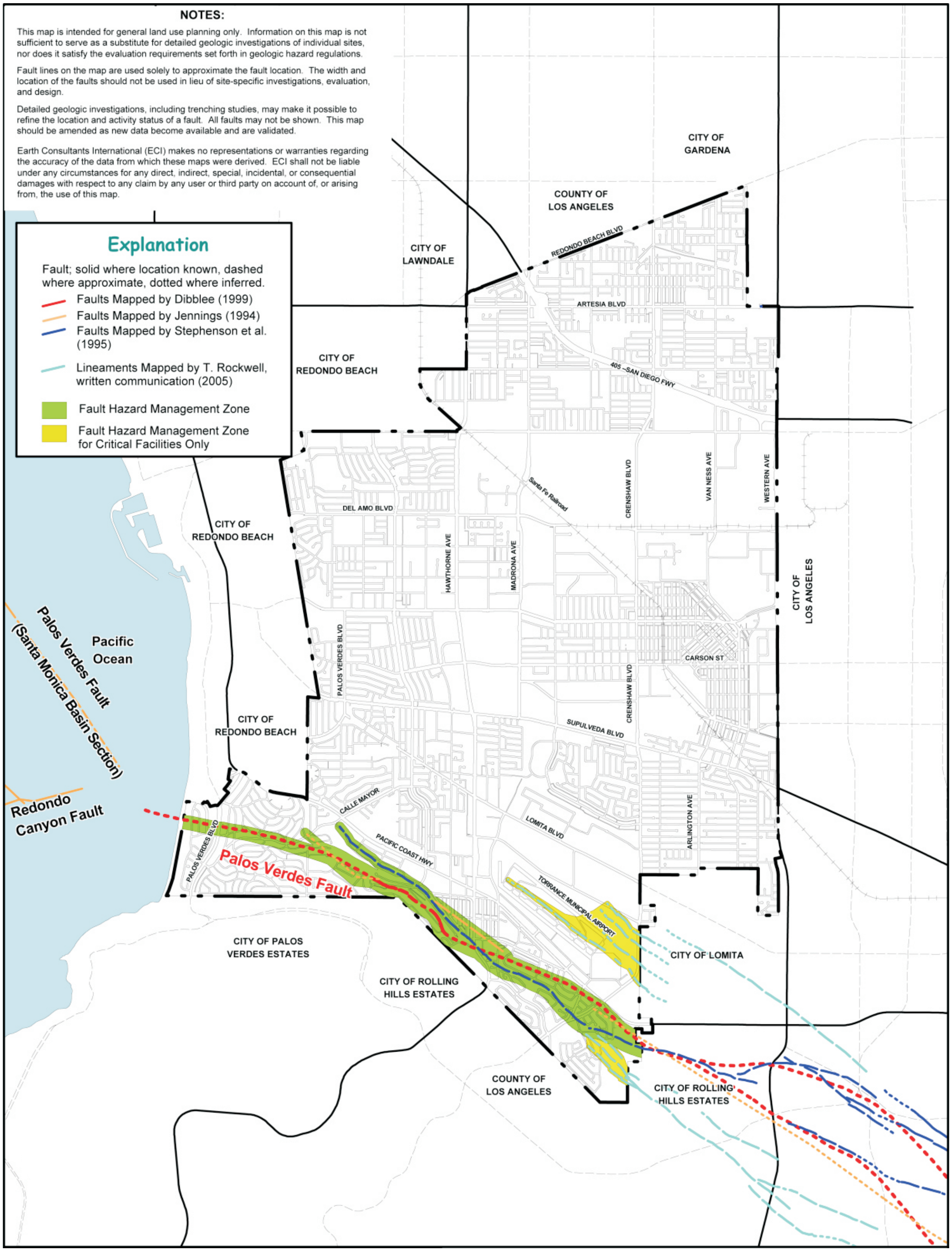
The most receptive areas to slope instability are areas with slope grades of 15 percent or higher, found in Torrance near the Palos Verdes Hills and other areas in western Torrance. The risks related to landslides and liquefaction in these areas would be reduced by the use of building setbacks and restrictions.

Collapsible and Compressible Soils

Areas of recently active drainage channels in Torrance would be the areas most susceptible to soil collapse because of the young deposits of alluvial soil. The potential for soils to collapse should be evaluated on a site-specific basis as part of the geotechnical studies for development. A number of construction-related mitigation techniques reduce the risk of soil collapse. These techniques include excavation and recompaction, or the in-place presaturation and preloading of the susceptible soils to induce collapse. After construction, infiltration of water into the subsurface soils should be minimized by proper surface drainage design, which directs excess runoff to catch basins and storm drains. Soil engineering reports, as required by Torrance Municipal Code (Section 81.2.42, Grading Permit Requirements), would disclose the geological and soil conditions of a development site prior to building approval and construction.

Areas of the City where compressible soils are most likely to occur are the active and recently active stream channels, beach deposits, and young alluvial fan deposits. When development is planned within areas that contain compressible soils, a geotechnical soil analysis is required to identify the presence of this hazard. The analysis should consider the characteristics of the soil column in that specific area, the load of any proposed fills and structures that are planned, the type of structure (i.e., a road, pipeline, or building), and the local groundwater conditions. In cases where it is not feasible to remove the compressible soils, buildings can be supported on specially engineered foundations that may include deep caissons or piles anchored in noncompressible materials underlying the weak soils.

Fault Map with Fault Hazard Management Zones



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.

Fault lines on the map are used solely to approximate the fault location. The width and location of the faults should not be used in lieu of site-specific investigations, evaluation, and design.

Detailed geologic investigations, including trenching studies, may make it possible to refine the location and activity status of a fault. All faults may not be shown. This map should be amended as new data become available and are validated.

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.

Source: Earth Consultants International 2005

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Subsidence

Instances of subsidence in Torrance are associated with oil and gas extraction. However, subsidence has been reduced over the last 30 years and from about three centimeters per year between 1978 and 1989 and about two millimeters per year between 1989 and 1994. Subsidence due to groundwater pumping has not been a significant risk in the past, but increases in groundwater extraction in the future may cause new sources of ground subsidence. The City has taken actions to reduce this risk:

- Increased use of reclaimed water, stormwater, or imported water.
- Implementation of artificial recharge programs.
- Determination of the safe yields of the groundwater basins, so that available supplies can be balanced with extraction.
- Monitoring of the groundwater and basin conditions.
- Establishment of a monitoring program to detect changes in ground elevations above producing aquifers.
- Protecting groundwater quality.
- Reducing long-term water demand with specific programs of water conservation.
- Acquiring additional imported water supplies, and encouraging water conservation through public education.

Erosion

Wind erosion does not pose a significant risk to the City since the majority of the area has been developed, leaving few exposed soil surfaces. Erosion caused by water occurs along the coastline where waves wear down soil, rock, and sediments. Short-term and long-term erosion control measures would help to maintain the natural structures of these areas.

The City has almost reached its buildout capacity; most of the new development in the City would be redevelopment or small infill projects. New development would be required to follow the building, construction, and design features that reduce impacts related to soil instability. The Torrance Building Code incorporated into the municipal code (Division 8, Chapter 1, *Building Code*) includes restrictions and practices that must be followed by developers in the City of Torrance. Impacts related to soil instability would therefore be less than significant.

5.5.4 Relevant General Plan Update Policies

Safety Element

- To protect the community from hazards related to earthquakes, seismic-related activity, and flooding. (Objective S.1)

- Adopt and strictly enforce the most recent State regulations governing seismic safety and structural design to minimize damage to structures from seismic or geologic hazards. (Policy S.1.1)

- Reduce the risk associated with structures which would likely be seriously damaged during a major earthquake, such as those located in high-risk seismic areas and buildings that do not meet current seismic codes. (Policy S.1.2)

- Monitor on-going research on regional seismic and seismic-related hazards, and support efforts to identify the location, potential activity, and dangers associated with earthquake faults. (Policy S.1.3)

- Require increased levels of structural protection for critical facilities such as hospitals, police and fire facilities, communication and emergency operations centers, and places of community assembly. (Policy S.1.4)

- Provide and maintain adequate flood control facilities, and limit development within flood-prone areas. (Policy S.1.5)

5.5.5 Existing Regulations

- Alquist-Priolo Earthquake Fault Zoning Act
- Seismic Hazards Mapping Act (SHMA)
- Natural Hazards Disclosure Act.
- Uniform Building Code (UBC) and California Building Code (CBC)
- Unreinforced Masonry Law
- City of Torrance Municipal Code
    - *Soil Engineering Report.* “The soil engineering report required by Section J104.4 shall include data regarding the nature, distribution, and strength of existing soils, conclusions, and recommendations for grading and paving procedures, effect of the development on adjacent properties, and design criteria for corrective measures, including buttress fills, when necessary, and opinions and recommendations covering adequacy of sites to be developed by the proposed grading, including the stability of slopes. During grading, all necessary reports, compaction data, and soil engineering and engineering geology recommendations shall be submitted to the Building Official by the soil engineer and engineering geologist. Recommendations included in the report and approved by the Building Official shall be incorporated in the grading or paving plans and specifications (Torrance Municipal Code 81.2.42. Grading Permit Requirements).”

    - *Engineering Geology Report.* “The engineering geology report required by Section J104.4 shall include an adequate description of the geology of the site, conclusions, and recommendations regarding the effect of geologic conditions on the proposed development, and the opinions and recommendations covering the adequacy of sites to be developed by the proposed grading or construction. This report shall include analysis of seismic activity and seismic *fault* zones and their influence of the proposed development (Torrance Municipal Code 81.2.42. Grading Permit Requirements).”

5.5.6 Level of Significance Before Mitigation

Upon implementation of regulatory requirements and standard conditions of approval, the following impacts would be less than significant: 5.5-1 and 5.5-2.

5.5.7 Mitigation Measures

No mitigation measures are necessary.

5.5.8 Level of Significance After Mitigation

No significant unavoidable adverse impacts relating to geology and soils have been identified, and no mitigation measures are necessary.

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