5.6 GEOLOGY AND SOILS

5.6.1 Regulatory Setting

Alquist-Priolo Earthquake Fault Zoning Act

The Alquist-Priolo Earthquake Fault Zoning Act (formerly the Alquist-Priolo Special Studies Zone Act), signed into law December 1972, requires the delineation of zones along active faults in California. The purpose of the Alquist-Priolo Act is to regulate development on or near active fault traces to reduce the hazard of fault rupture and to prohibit the location of most structures for human occupancy across these traces.[1] Cities and counties must regulate certain development projects within the zones, which includes withholding permits until geologic investigations demonstrate that development sites are not threatened by future surface displacement (Hart 1997).

Seismic Hazards Mapping Act

The Seismic Hazards Mapping Act was developed to protect the public from the effects of strong groundshaking, liquefaction, landslides, or other ground failure, and from other hazards caused by earthquakes. This act requires the State Geologist to delineate various seismic hazard zones and requires cities, counties, and other local permitting agencies to regulate certain development projects within these zones. Before a development permit is granted for a site within a seismic hazard zone, a geotechnical investigation of the site has to be conducted and appropriate mitigation measures incorporated into the project design. Seismic Hazard maps have been completed for much of the Southern California region and are still being developed for the northern California region. Until such time that mapping is completed for the all quadrangle areas within the Los Angles Basin Network, the Seismic Safety and Safety Element for the individual cities and counties would be used to determine whether the site is within an area potentially subject to seismic hazards.

California Building Code

The California Building Code is another name for the body of regulations known as the California Code of Regulations (CCR), Title 24, Part 2, which is a portion of the California Building Standards Code (CBSC 1995). Title 24 is assigned to the California Building Standards Commission, which, by law, is responsible for coordinating all building standards. Under state law, all building standards must be centralized in Title 24 or they are not enforceable (Bolt 1988).

Published by the International Conference of Building Officials, the Uniform Building Code (UBC) is a widely adopted model building code in the United States. The California Building Code incorporates by reference the UBC with necessary California amendments. About one-third of the text within the California Building Code has been tailored for California earthquake conditions (ICBO 1997).

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[1] A "structure for human occupancy" is defined by the Alquist-Priolo Act as any structure used or intended for supporting or sheltering any use or occupancy that has an occupancy rate of more than 2,000 person-hours per year.

5.6.2 Environmental Setting

5.6.2.1 San Francisco Bay Area Network

Geology

North trending mountain ranges and valleys of the Coast Range geomorphic province characterize the San Francisco Bay Region. The predominant feature is the geologic structural depression that forms the San Francisco Bay. The Santa Cruz Mountains border the San Francisco Bay to the west and the Diablo Range forms the upland areas to the east. North of San Francisco, mountains and hills of more extreme relief form the Marin Peninsula. The broad, low-relief Santa Clara Valley lies between the Santa Cruz Mountains and the Diablo Range in the south San Francisco Bay region. The marginal lands surrounding the San Francisco Bay are low-lying, alluviated plains that slope gently bayward from the bordering uplands.

The San Francisco Bay Area Network in northern California is located primarily within the low-lying flatland regions surrounding the San Francisco Bay margin. The Peninsula Backbone on the San Francisco peninsula extends from the relatively flat Santa Clara Valley along the base of the eastern Santa Cruz Mountain foothills. The East Bay Backbone extends along the East Bay Plain, west of the Diablo Range.

The Coast Range Mountains in this region are composed of marine sedimentary and volcanic rocks that form the Franciscan Assemblage. The Franciscan Assemblage is Cretaceous-aged (65 to 136 million years old) and contains primarily greenstone (altered volcanic rocks), basalt, chert (ancient silica-rich ocean deposits), and sandstone that originated as ancient sea floor sediments. These rocks are found in northwest-trending ridges and valleys that extend along the Pacific Coast from Oregon 400 miles south into Southern California. The alluvial plains that comprise the San Francisco Bay margin are composed of Quaternary-aged (up to 2 million years old) sediments consisting of unconsolidated stream and basin deposits, intertidal deposits and artificial fills. The stream and basin sediments form the majority of the marginal plains and the intertidal deposits are found closer to the edge of the San Francisco Bay. Historic shoreline reclamation resulted in the varying types of man-made artificial fill that overlie the bayland intertidal deposits.

Soils

A wide variety of soils form on the alluvial plains bordering the San Francisco Bay. The United States Department of Agriculture (USDA) Natural Resource Conservation Service (NRCS) defines these soil associations. Soils within the Project region are generalized within four major classifications. Depending on localized conditions, these general classifications are grouped into more specific soil types depending on location, localized climate and slope. The Santa Clara valley and the alluvial plains surrounding the San Francisco Bay are classified as deep alluvial plain and flood plain soils. These soil occupy the valleys in areas with higher rainfall and are considered productive when drained and fertilized. Soils occurring closer to the bay margin are generally dark-colored clays that have a high water table or are subject to overflow from flooding. Throughout California, these soils are typically used for wheat barley and native pasture land. Soils that occupy the extreme edge of the San Francisco Bay are characterized by a moderate to high content of soluble salts and are referred to as “alkali soils” and can be used for salt grass pasture or for production of salt tolerant crops. Soils in northern San Mateo County, in the eastern portion of the city of San Francisco and in Marin County are classified as residual soils with a moderate depth to underlying bedrock. These are natural grassland soils occurring where annual rainfall is considered moderately high. Residual soils of this group constitute some of the best natural grazing lands in California.[2]

Seismicity

The San Francisco Bay Area contains both active and potentially active faults and is considered a region of high seismic activity.[3] The 1997 UBC locates the entire Bay Area within Seismic Risk Zone 4. Areas within Zone 4 are expected to experience maximum magnitudes and damage in the event of an earthquake.

Earthquakes pose especially high risks to the San Francisco Bay Area because of its close proximity to active faults with relatively frequent past movements. The National Earthquake Prediction Evaluation Council, formed after to the 1989 Loma Prieta earthquake, evaluated the probability of one or more earthquakes of Richter magnitude 7 or higher occurring in the San Francisco Bay Area within the next 30 years. The result of the evaluation indicated a 67 percent likelihood that such an earthquake event will occur in the Bay Area between 1990 and 2020 (Schwartz 1994).

The San Andreas and the Hayward faults are the two principally active, strike-slip-type faults[4] in the Bay Area and have experienced movement within the last 150 years. The San Andreas fault is a major structural feature in the region and forms a boundary between the North American and Pacific tectonic plates. Other principal faults capable of producing significant Bay Area groundshaking are listed in Table 5.6-1 and include the San Gregorio–Hosgri Fault Zone, the Rodger’s Creek–Healdsburg fault, the Calaveras fault, and the Concord–Green Valley fault (see Figure 5.6-1). A major seismic event on any of these active faults could cause significant groundshaking within the San Francisco Bay Area Network, as was experienced during earthquakes in recent history, namely the 1906 San Francisco earthquake, the 1868 Hayward earthquake, and the 1989 Loma Prieta earthquake.

SHAKING INTENSITY

While the magnitude is a measure of the energy released in an earthquake, intensity is a measure of the groundshaking effects at a particular location. Shaking intensity can vary depending on the overall magnitude, distance to the fault, focus of earthquake energy, and type of geologic material. The Modified Mercalli (MM) intensity scale (Table 5.6-2) is commonly used to measure earthquake effects due to groundshaking. The MM values for intensity range from I (earthquake not felt) to XII (damage nearly total). MM intensities ranging from IV to X could cause moderate to significant

2 Division of Agricultural Science, University of California, Generalized Soil Map of California, 1951.

3 An *active* fault is defined by the State of California as a fault that has had surface displacement within Holocene time (approximately the last 10,000 years). A *potentially active* fault is defined as a fault that has shown evidence of surface displacement during the Quaternary (last 1.6 million years), unless direct geologic evidence demonstrates inactivity for all of the Holocene or longer. This definition does not, of course, mean that faults lacking evidence of surface displacement are necessarily inactive. *Sufficiently active* is also used to describe a fault if there is some evidence that Holocene displacement occurred on one or more of its segments or branches (Hart 1997).

4 “Strike-slip” faults primarily exhibit displacement in a horizontal direction, but may have a vertical component.

Table 5.6-1. Active Faults in the Vicinity of the San Francisco Bay Area Network

Fault Zone	*Location Relative to the Metromedia Project*	*Recency of Faulting*[a]	*Historical Seismicity*[b]	*Slip Rate*[c] *(mm/year)*	*Maximum Moment Magnitude*[d]
San Andreas (Peninsula and Golden Gate segments)	Adjacent	Historic	M 7.1: 1989 M 8.25: 1906 M 7.0: 1838 Many <M 6	17.0	7.3
San Gregorio–Hosgri Fault Zone	8 miles southwest	Holocene; Late Quaternary	Many M 3-6.4	5.0	7.3
Hayward	18 miles east	Historic	M 6.8: 1868 M 7.0: 1838 Many <M 4.5	9.0	6.9
Calaveras	25 miles east	Historic	M 6.1: 1984 M 5.9: 1979 Many <M 6.5	15.0 (Maximum)	6.8
Concord–Green Valley	30 miles northeast	Historic	Active Creep[e]	6.0	6.9
Healdsburg–Rodgers Creek	36 miles north	Holocene	NA	9.0	7.0

[a] Recency of faulting from Jennings, 1994. Historic: displacement during historic time (within last 200 years), including areas of known fault creep; Holocene: evidence of displacement during the last 10,000 years; Quaternary: evidence of displacement during the last 1.6 million years; Pre-Quaternary: no recognized displacement during the last 1.6 million years (but not necessarily inactive).

[b] Richter magnitude (M) and year for recent and / or large events.

[c] Slip Rate = Long-term average total of fault movement including earthquake movement, slip, expressed in millimeters.

[d] The Maximum Moment Magnitude is an estimate of the size of a *characteristic* earthquake capable of occurring on a particular fault. Moment magnitude is related to the physical size of a fault rupture and movement across a fault. Richter magnitude scale reflects the maximum amplitude of a particular type of seismic wave. Moment magnitude provides a physically meaningful measure of the size of a faulting event (CDMG 1997b). Richter magnitude estimations can be generally higher than moment magnitude estimations.

[e] Slow fault movement that occurs over time without producing an earthquake.

NA = Not applicable and / or not available.

Sources: Jennings, C.W. 1994, Fault Activity Map of California (with Appendix), California Division of Mines and Geology, Geologic Data Map No. 6; Peterson, M.D., Bryant, W.A., Cramer, C.H., 1996, Probabilistic Seismic Hazard Assessment for the State of California by the California Department of Conservation, Division of Mines and Geology, Open File Report 96-08, USGS Open-File Report 96-706.

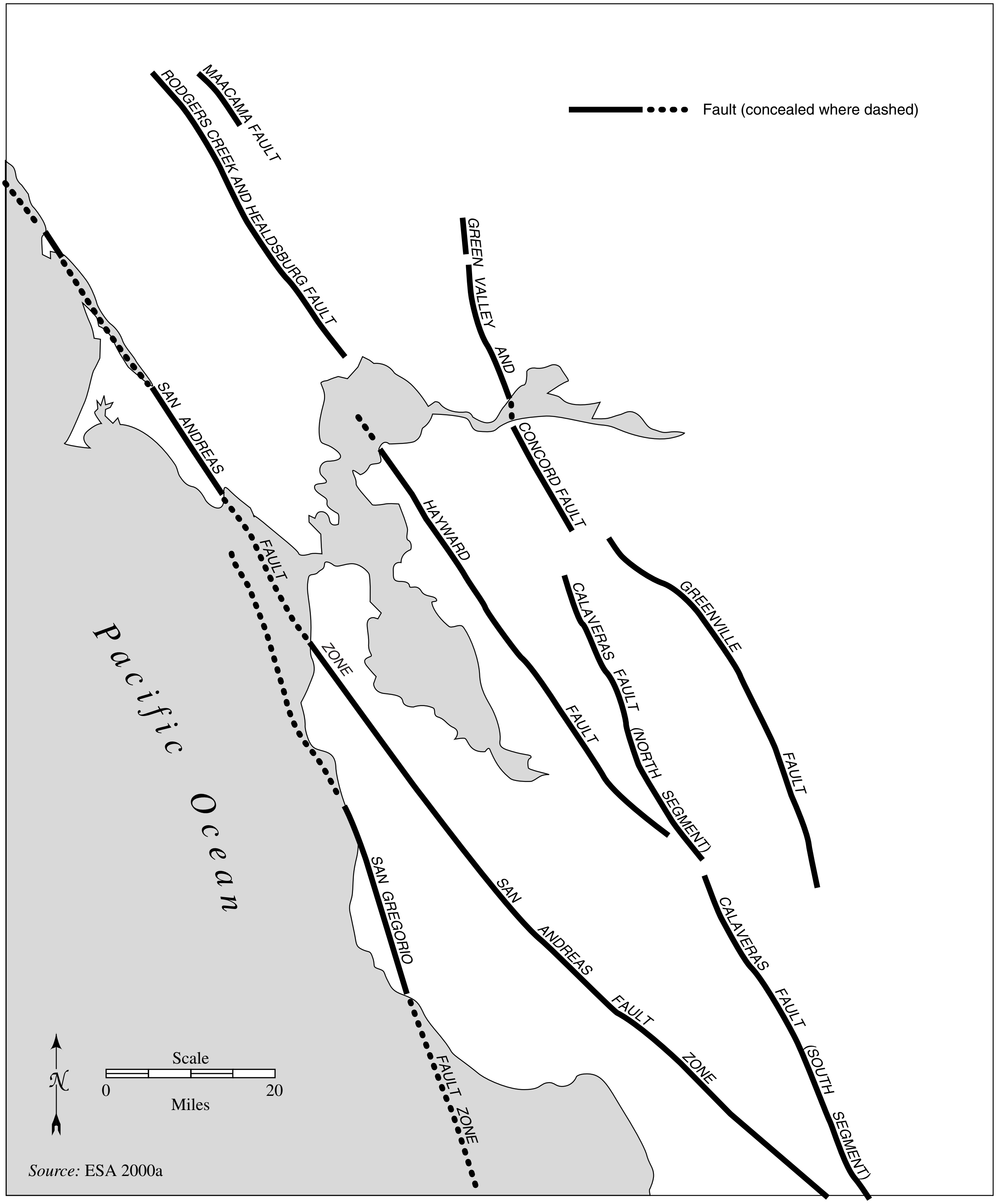

Figure 5.6-1. Principal Active Faults in the San Francisco Bay Area

structural damage.[5] Earthquakes on the various active and potentially active San Francisco Bay area fault systems are expected to produce a wide range of groundshaking intensities within the San Francisco Bay Area Network. The estimated maximum (moment) magnitudes (Table 5.6-1) represent characteristic earthquakes on particular faults.[6]

SAN ANDREAS FAULT

On the San Francisco Peninsula, a characteristic earthquake on the San Andreas fault with estimated moment magnitude of 7.3 could produce MM intensities ranging from very strong (MM-VII) to very violent shaking (MM-X) (ABAG 1998b). The range of effects typically associated with these intensities could include some structural damage, such as cracks in walls and chimneys, to total building collapse (Table 5.6-2). As a comparison, the 1906 San Francisco earthquake, with a moment magnitude of 7.8 located north on the San Andreas fault, produced shaking intensities on the San Francisco Peninsula ranging from violent (MM-IX) to very violent (MM-X) on the San Francisco Peninsula. The 1989 Loma Prieta earthquake, with a moment magnitude of 6.9 located south on the San Andreas fault, produced moderate (MM-VI) to strong (MM-VII) shaking intensities (ABAG 1998c).[7]

HAYWARD FAULT / SAN GREGORIO–HOSGRI FAULT ZONE

Shaking intensities ranging from strong (MM-VII) to very strong (MM-VIII) would be expected from a characteristic earthquake (moment magnitude 6.9) on the Hayward fault. Similar shaking intensities would be expected on the San Gregorio–Hosgri Fault Zone. Earthquakes within this range of intensities are felt by everyone and can cause furniture to overturn, structural damage, and partial collapse in some buildings (ABAG 1995). In addition to wide-spread damage in the East Bay cities of Oakland and Hayward, the 1868 earthquake on the Hayward fault (approximate magnitude 7) produced shaking intensities ranging from MM-VII to MM-VIII on the San Francisco Peninsula and caused some structural damage and partial building collapse. San Francisco sustained building collapse and underground utility failure.

OTHER REGIONAL ACTIVE FAULTS

Characteristic earthquakes on the Calaveras, Concord–Green Valley, Rodger's Creek–Healdsburg, and Greenville faults would be expected to produce intensities from light (V) to moderate (VI) in the MFN Project region. An earthquake with these MM intensities would likely be felt by most people but would result in little or no structural damage (ABAG 1998b).

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5 The damage level represents the estimated overall level of damage that will occur for various MM intensity levels. The damage, however, will not be uniform. Some buildings will experience substantially more damage than this overall level, and others will experience substantially less damage. Not all buildings perform identically in an earthquake. The age, material, type, method of construction, size, and shape of a building all affect its performance (ABAG 1998a).

6 Moment magnitude is related to the physical size of a fault rupture and movement across a fault. Richter magnitude scale reflects the maximum amplitude of a particular type of seismic wave. Moment magnitude provides a physically meaningful measure of the size of a faulting event (CDMG 1997b).

7 Intensities for the San Francisco and Loma Prieta earthquakes are based on a model of the San Francisco earthquake and do not represent actual measurements (ABAG 1998c).

Table 5.6-2. Modified Mercalli Intensity Scale

Intensity Value	*Intensity Description*	*Average Peak Acceleration*
I	Not felt except by a very few persons under especially favorable circumstances.	< 0.0015 g
II	Felt only by a few persons at rest, especially on upper floors on buildings. Delicately suspended objects may swing.	< 0.0015 g
III	Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration similar to a passing of a truck.	< 0.0015 g
IV	During the day felt indoors by many, outdoors by few. At night, some awakened. Sensation like heavy truck striking building.	0.015 g-0.02 g[1]
V	Felt by nearly everyone, many awakened; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed.	0.03 g-0.04 g
VI	Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys.	0.06 g-0.07 g
VII	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.	0.10 g-0.15 g
VIII	Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Sand and mud ejected in small amounts. Changes in well water.	0.25 g-0.30 g
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Underground pipes broken.	0.50 g-0.55 g
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Shifted sand and mud. Water splashed (slopped) over banks.	> 0.60 g
XI	Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.	> 0.60 g
XII	Damage total. Practically all works of construction are damaged greatly or destroyed. Waves seen on ground surface. Lines of sight and level are distorted. Objects are thrown upward into the air.	> 0.60 g

1 g = gravity = 980 centimeters per second squared

Source: Bolt, Bruce A. 1988. *Earthquakes*, W.H. Freeman and Company, New York.

5.6.2.2 Los Angeles Basin Network

Geology

The southern portion of the project extends from the San Fernando Valley and eastern Santa Monica Mountains in Los Angeles County to the Santa Ana River plain in Orange County. The Santa Monica Mountains, associated with the Traverse Ranges of southern California, are an east-west trending coastal range forming the northern edge of the Santa Monica Bay. Prominent basins and ranges in the Transverse Ranges include the Ventura basin and the San Gabriel and San Bernardino Mountains to the east of the project area. The mountains are steep, rugged and generally underlain by older, harder bedrock formations. The Peninsular Ranges, a northwest-southeast trending range, extend from Mexico to the Los Angeles area including the San Jacinto and Santa Ana Mountains southeast of the project area. Local northwest-southeast trending coastal hills within the project area associated with the Peninsular Ranges include Palos Verde, Beverly Hills, and Baldwin Hills.

Bedrock including sedimentary, igneous, or metamorphic rock, is found in the mountains and hills. Sedimentary bedrock found in portions of the Santa Monica mountains and Palos Verde Hills can be less stable and prone to landslide. Much of the project is located on generally flat, alluvial terrain with slopes of less than 10 percent, between these hills and mountain ranges. However, portions of the project would traverse the Baldwin Hills and Palos Verde formation and cross the Santa Monica Mountains at Beverly Glen Boulevard.

Soils

Soils throughout the Los Angeles Basin Network differ in origin, composition, and slope development. The formation of surficial soils depends on the topography, climate, local vegetation, and the material on which the soil profile is developed. Surficial deposits (including surface soils) within the low lying plains consist of relatively recent sediments (sand, gravel, silt, and clay) formed by alluvial processes in streams and near coastal areas. The younger alluvial soils tend to be relatively unconsolidated and poorly cemented. Where these deposits are mainly low density sand and partially saturated (shallow or perched groundwater) liquefaction potential is the highest. Construction on these soils can range from acceptable to very poor. Older alluvium (gravel and sand with much less silt and clay) generally occupies the higher valleys, having been uplifted by faulting. The older sediments tend to be more cemented and consolidated, leading to higher stability.

Depending on the composition and drainage characteristics, soils in the Los Angeles Basin Network often are not suitable for agriculture and are only suitable for grazing, wildlife habitat, orchards or residential and industrial uses. Applicable USDA-NRCS soil surveys for the Los Angeles and Orange Counties provide classification and descriptions of each soil type encountered in the Southern California area.

Seismicity

Southern California is subject to seismic activity similar to northern California. The region contains numerous lateral strike slip faults similar to the San Andreas and various identified and hidden blind thrust faults. A fault trace is the surface expression of a particular fault. Buried or blind thrust faults are thought to underlay much of the southern California region. These “buried” faults do not exhibit readily identifiable traces on the earth's surface and are typically at considerable depth within the underlying geologic formation. Although these faults typically do not offset surface deposits, they can generate substantial groundshaking.

Major fault systems in the project area are shown in Figure 5.6-2 and indicated in Table 5.6-3. Two types of faults are listed in the table: Class A faults and Class B faults. Class A faults have slip rates greater than 5 millimeters per year and substantial historic seismic data, while Class B faults are faults that lack the historic seismic data to develop recurrence intervals of large events. In Southern California, scientists estimate that the probability of a magnitude 7.0 or greater earthquake by the year 2024 approaches 80 to 90 percent. The four major hazards generally associated with earthquakes are ground shaking, fault surface rupture (ground displacement), liquefaction ground failures, and settlement. Table 5.6-4 lists known blind thrust faults in the Los Angeles area.

SHAKING INTENSITY

Groundshaking in the Los Angeles Basin Network area could be caused by nearby faults such as the San Andreas and San Jacinto Faults or by faults within the project area such as the Newport-Inglewood Fault and subsurface blind thrust faults. Similar groundshaking intensities within the project area could result from movement along major faults outside the project area or from local minor faults within the project area. Shaking intensities would be expected to range from MM-VII to MM-IX in the southern portion of the project area and could reach MM-IX+ in portions of west, central, and south Los Angeles. Structural damage could be severe in localized areas throughout the city depending on the source of the seismic activity.

SAN ANDREAS FAULT

The San Andreas fault is located approximately 20 miles east of portions of the project site in downtown Los Angeles and the San Fernando Valley. The last major earthquake in Southern California generated by the San Andreas fault was the 1857 Fort Tejon quake (magnitude 7.5-8.5). This event generated intensities of MM-X to MM-XI. The United States Geological Survey (USGS) has determined that San Andreas is capable of generating a maximum probable earthquake of 8.3 on the Richter Scale. A maximum probable earthquake is the largest earthquake that is likely to occur in a 100-year period. Shaking intensities could range form MM-VII to MM-VIII within the project area. Despite the distance of the fault from the project area, a major earthquake along the San Andreas fault could cause severe damage to structures in the city of Los Angeles.

NEWPORT-INGLEWOOD FAULT ZONE

The Newport Inglewood Fault Zone extends from off the coast west of Dana Point, through Newport Beach, Long Beach and Torrance. The fault zone is suspected of having a probable maximum Richter Scale magnitude of 7.0 and a maximum credible earthquake magnitude of 7.7. Shaking intensities could be as high as MM-IX within the Irvine local project area. The Fault zone is responsible for the Long Beach earthquake (1933), the Gardena earthquake (1941) and the Torrance-Gardena earthquake (1941). The recurrence interval for an event of magnitude 7.7 is approximately 1,000 years, and because the southern segment of the zone moved 40 years ago, the probability of a large event is considered low.

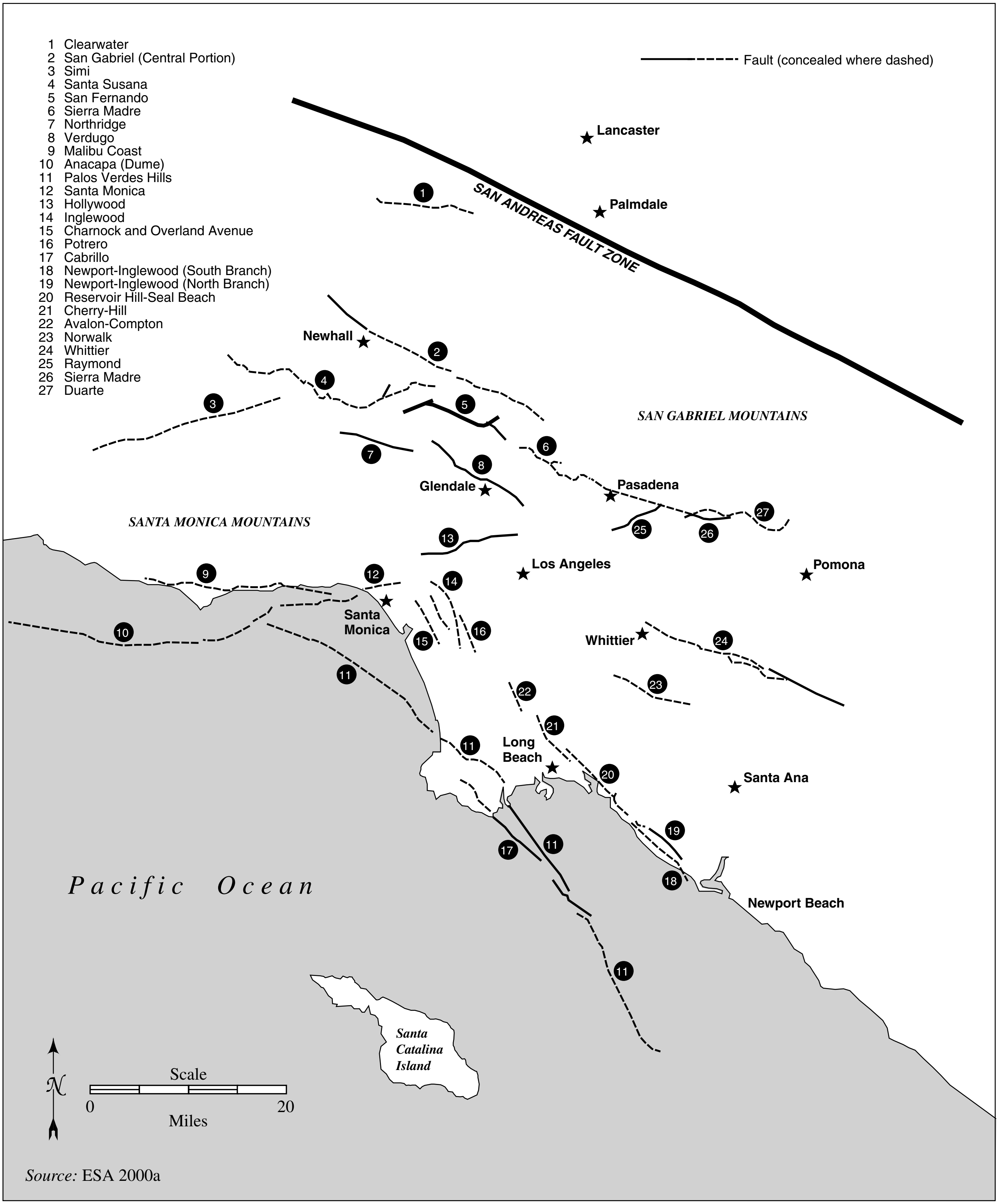

Figure 5.6-2. Principal Active Faults in the Los Angeles Basin Area

Table 5.6-3. Major Faults in the Project Vicinity

Fault Zone	*Counties*	*Recency of Faulting*[a]	*Slip Rate*[b] *(mm/year)*	*Maximum Moment Magnitude*[c]
CLASS A FAULTS				
San Andreas	Los Angeles, San Bernardino, Riverside, Ventura, Imperial	Historic	34.00	6.8 to 7.9
San Jacinto	San Bernardino, Riverside, and Imperial	Holocene, Late Quaternary		6.6 to 7.2
Whittier/Elsinore	Imperial	Holocene	2.50-5.00	6.8 to 7.1
CLASS B FAULTS				
Sierra Madre	Los Angeles	Holocene, Late Quaternary	3.00	6.7 to 7.0
Santa Susana	Los Angeles, Ventura	Historic, Late Quaternary	5.00	6.6
Newport-Inglewood	Los Angeles, Orange	Late Quaternary	1.00	6.9
Oak Ridge	Los Angeles	Holocene, Late Quaternary	4.00	6.9

[a] Recency of faulting from Jennings (1994). Historic: displacement during historic time (within last 200 years), including areas of known fault creep; Holocene: evidence of displacement during the last 10,000 years; Quaternary: evidence of displacement during the last 1.6 million years; Pre-Quaternary: no recognized displacement during the last 1.6 million years (but not necessarily inactive). Multiple periods are listed when different branches have shown displacement for different geologic periods.

[b] Slip Rate = Long-term average total of fault movement including earthquake movement, slip, expressed in millimeters.

[c] The Maximum Moment Magnitude is an estimate of the size of a *characteristic* earthquake capable of occurring on a particular fault. Moment magnitude is related to the physical size of a fault rupture and movement across a fault. Richter magnitude scale reflects the maximum amplitude of a particular type of seismic wave. Moment magnitude provides a physically meaningful measure of the size of a faulting event (CDMG 1997b). Richter magnitude estimations can be generally higher than moment magnitude estimations. Ranges are provided for certain fault zones due to different magnitudes calculated for different branches of the fault zone.

NA = Not applicable and / or not available.

Sources: Jennings, C. W., 1994, Fault Activity Map of California (with Appendix), California Division of Mines and Geology, Geologic Data Map No. 6; Peterson, M. D., Bryant, W. A., Cramer, C. H., 1996, Probabilistic Seismic Hazard Assessment for the State of California by the California Department of Conservation, Division of Mines and Geology, Open File Report 96-08, USGS Open-File Report 96-706.

Table 5.6-4. Blind Thrust Faults in the Los Angeles Area

Fault Zone	County	MAXIMUM EARTHQUAKE		Historical Seismicity
		Probable	*Credible*	
Elysian Park Wilshire	Los Angeles	5.5 – 6	7+	Whittier 5.9
Compton-Los Alamitos	Los Angeles	5 – 6?	7+	Little known
Torrance Wilmington	Los Angeles	5 – 6?	7+	Little known
San Fernando Ramp	Los Angeles	6.7	7+	Northridge 6.7
Source: City of Los Angeles, City-wide General Plan Framework, 1995				

OTHER FAULTS IN THE SOUTHERN CALIFORNIA REGION

Class B faults and blind thrust faults are numerous in the Southern California area and are capable of causing severe groundshaking in local areas. The Northridge earthquake of 1994 is an example of an earthquake occurring within a blind thrust fault zone which caused significant structural damage to buildings and freeways throughout the Los Angeles area.

Methane and Hydrogen Sulfide Gas Seepage

Naturally occurring methane gas and hydrogen sulfide gas (H_2S) have been known to migrate into shallow geology deposits in certain areas of the Los Angles Basin Network area. In 1985, an explosion occurred in the basement of a commercial retail outlet store (Ross Dress for Less) in Los Angeles caused by methane accumulation through subsurface seepage. Methane gas and H_2S can follow fissures or improperly abandoned oil wells to the surface or near-surface strata from deeper oil producing formations. Areas above known petroleum resources are of particular concern including central Los Angeles (Fairfax District), Huntington Beach, and Brea. Methane may be trapped under impervious surfaces where concentrations can cause explosion or hazardous breathing conditions. H_2S can be toxic to humans at elevated concentrations. Excavations may experience pockets of accumulated methane or H_2S gas at shallow depths.

5.6.2.3 Statewide Geologic Hazards

The San Francisco Bay Area Network and Los Angles Basin Network regions have similar soil types, seismic regimes, and geology. The geology in both areas can vary from upland areas underlain by bedrock to alluvial flatlands. Because of this varied geology, geologic hazards that could affect the proposed networks include expansive soils, slope instability (landsliding), settlement, and erosion.

Expansive Soils

Expansive soils possess a "shrink-swell" characteristic. Shrink-swell is the cyclic change in volume (expansion and contraction) that occurs in fine-grained clay sediments from the process of wetting and drying. Structural damage may result over a long period of time, usually the result of inadequate soil and foundation engineering or the placement of structures directly on expansive soils.

Landsliding

The susceptibility of land (slope) failure is dependent on the slope and geology as well as the amount of rainfall, excavation, or seismic activities. A landslide is a mass of rock, soil, and debris displaced down-slope by sliding, flowing, or falling. Steep slopes and down-slope creep of surface materials characterize areas most susceptible to landsliding. Landslides are least likely in areas with low relief such as valleys in the Los Angeles basin, Santa Clara Valley, and along the margin of the San Francisco Bay.

Settlement

Settlement is the depression of the bearing soil when a load, such as that of a building or new fill material, is placed upon it. Soils tend to settle at different rates and by varying amounts depending on the load weight, which is referred to as differential settlement. Differential settlement presents a greater hazard than total settlement in both network areas because of variations in the thickness of previous and new fills, as well as natural variations in the thickness and compressibility of soils.

Erosion

Erosion is generally not a serious problem in either the San Francisco Bay Area or Los Angeles Basin Network areas because the majority of the alignments are developed, and slopes are more gradual. However, during construction, exposed soils would be subject to stormwater erosion.

5.6.2.4 Statewide Seismic Hazards

The San Francisco Bay Area and Los Angles Basin Networks could experience the effects of a major earthquake from one of the active or potentially active faults in the San Francisco Bay Area and Southern California, respectively. The four major hazards associated with earthquakes are fault surface rupture (ground displacement), groundshaking, ground failure, and settlement.

Groundshaking

The project area could be affected by strong groundshaking caused by a major earthquake during the next 30 years. The composition of underlying soils in areas located relatively distant from faults can intensify groundshaking. Portions of Northern and Southern California that experienced the worst structural damage were not those closest to the fault, but rather those with soils that magnified the effects of groundshaking.[8] Groundshaking may affect areas hundreds of miles

[8] Groundshaking can be described in terms of peak acceleration, peak velocity, and displacement of the ground. Areas that are underlain by bedrock tend to experience less groundshaking than those underlain by unconsolidated sediments such as artificial fill.

distant from the earthquake's epicenter. Historic earthquakes have caused strong groundshaking and damage in the San Francisco Bay Area and in Southern California. Groundshaking from an earthquake typically causes more damage than surface rupture because groundshaking is widespread. Seismic ground waves can cause damage or collapse to some structures, and can fracture or sever underground utility conduits.

Surface Fault Rupture

Surface expression of fault rupture is typically observed and expected on or within close proximity to the causative fault.[9] The magnitude, sense, and nature of fault rupture can vary for different faults or even along different strands of the same fault. Future faulting is generally expected along different strands of the same fault (CDMG 1997a). Rupture failure along these potentially active faults could possibly be triggered by activity on the San Andreas Fault Zone.

The Alquist-Priolo Earthquake Fault Zoning Act (see further discussion under Regulatory Background section), requires the zonation of active faults in California. The purpose of the Alquist-Priolo Act is to regulate development on or near active fault traces to reduce the hazard of fault rupture. It is important to note, however, that surface fault rupture is not necessarily restricted to the area within the Alquist-Priolo Zone.

Liquefaction

Liquefaction is the process by which water-saturated soil materials lose strength and become susceptible to failure during strong groundshaking in an earthquake. The shaking causes the pore-water pressure in the soil to increase, thus transforming the soil from a solid to a liquid. Liquefaction has been responsible for ground failures during almost all of California's great earthquakes. Liquefaction can occur in areas characterized by water-saturated, cohesionless, granular materials at depths less than 40 feet (ABAG 1996). Liquefaction can occur in unconsolidated native or artificial fill sediments such as those located in reclaimed areas along the margin of San Francisco Bay or in areas of saturated, loosely consolidated sediments above a depth of 50 feet in the Los Angeles basin. The depth to groundwater also controls the potential for liquefaction in this area; the shallower the groundwater, the higher potential for liquefaction.

Four kinds of ground failure commonly result from liquefaction: lateral spread, flow failure, ground oscillation, and loss of bearing strength (ABAG 1996). A *lateral spread* is a horizontal displacement of surficial blocks of sediments resulting from liquefaction in a subsurface layer. Lateral spread occurs on slopes ranging between 0.3 and 3 percent and commonly displaces the surface by several meters to tens of meters. Lateral spreads of only a few feet damaged every major pipeline that broke during the 1906 San Francisco earthquake. *Flow failures* occur on slopes greater than 3 degrees and are primarily liquefied soil or blocks of intact material riding on a liquefied subsurface zone. *Ground oscillation* occurs on gentle slopes when liquefaction occurs at depth and no lateral displacement takes place. Soil units that are not liquefied may pull apart from each other and oscillate on the liquefied zone. Ground fissures can accompany ground oscillation and sand boils and damage underground structures and utilities. The *loss of bearing pressure* can

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9 Fault rupture is displacement at the earth's surface resulting from fault movement associated with an earthquake (Steinbrugge, et al. 1987).

occur beneath a structure when the underlying soil loses strength and liquefies. When this occurs, the structure can settle, tip, or even become buoyant and "float" upwards. Liquefaction and associated failures could damage foundations, disrupt utility service, and cause damage to roadways. Liquefaction potential is highest in the areas underlain by Bay fills, Bay mud, and unconsolidated alluvium.

Earthquake-Induced Settlement

Settlement of the ground surface can be accelerated and accentuated by earthquakes. During an earthquake, settlement can occur as a result of the relatively rapid compaction and settling of subsurface materials (particularly loose, non-compacted, and variable sandy sediments) due to the rearrangement of soil particles during prolonged groundshaking. Settlement can occur both uniformly and differentially (i.e., where adjoining areas settle at different rates). Areas within the project region susceptible to this type of settlement include areas underlain by artificial fills, unconsolidated alluvial sediments, and slope wash, and areas with improperly engineered construction fills.

Tsunami and Sieche

Tsunami are long-period, seismically induced sea waves caused by seafloor displacements (faulting or landslides). These waves are not readily apparent in deep water, but once they reach shallow coastal areas they cause a rapid in-coming tide or "run-up" on the beaches and harbors. Tsunami waves from distant earthquakes can take several hours to reach the California shoreline, providing ample warning time for coastal areas. However, near shore seismic events would allow for very little warning time. Elevation of run-ups are estimated to be from four to twelve feet based on previous occurrences, but very few events have occurred within historic times for analysis. Low-lying coastal areas can experience significant damage from flooding during a tsunami surge. Portions of the Los Angles Basin Network (LAX local, Marina Del Rey local, and the Irvine local) would be located near the coast within the estimated maximum run-up elevation. The Santa Monica local alignment would be substantially protected by the sea bluffs.

Seiches are generated by "sloshing" of water in an enclosed or partially enclosed body of water such as a reservoir. Seiches are seismically induced and can result in overtopping dams, which could result in complete dam failure. Southern California dam failure inundation zones extend into the urbanized valleys from the Stone Canyon Reservoir in the Santa Monica Mountains, and the Van Norman, Tujunga, and San Gabriel reservoirs in the San Gabriel Mountains.