7.15 GEOLOGIC HAZARDS AND RESOURCES

7.15 GEOLOGIC HAZARDS AND RESOURCES

In accordance with CEC requirements, this section of the AFC presents information on the geological and tectonic setting of the region and site vicinity. Following this discussion, geologic hazards and resources described to provide background information on the conditions surrounding the proposed project site and related facilities; including linear features. The discussion of geologic hazards includes surface fault rupture, strong ground shaking, liquefaction, mass wasting/slope stability, subsidence, and expansive soils. Potential impacts of the proposed project on the geologic resources at the site are also addressed. Based on this evaluation, measures are recommended to mitigate potential impacts from the SGGS.

The final portion of this section describes laws, ordinances, regulations, and standards (LORS) relevant to geologic impacts of the proposed project as well as the contacts in cognizant regulatory agencies. Required permits are also discussed.

7.15.1 Affected Environment

The proposed project site is located in the City of Rancho Cucamonga, San Bernardino County, California, and is approximately 9 miles north of the Santa Ana River. The SGGS is located within the extreme northern portion of the Peninsular Ranges Geomorphic Province, near the boundary with the Transverse Ranges Province to the north. Figure 7.15-1 shows the tectonic provinces and crustal blocks of southern California. The Peninsular Ranges Province is characterized by a series of generally northwest trending mountain ranges and intervening valleys. Extensive folding and faulting within the province has created this northwest trending fabric evident throughout the province. The majority of the Peninsular Ranges Province is characterized by Mesozoic to Paleozoic age granitic and metamorphic bedrock and includes the Perris block. The Perris block is underlain by lithologically diverse prebatholithic and metasedimentary rocks intruded by Cretaceous plutons of the Peninsular Ranges Batholith. Several erosion and deposition surfaces are developed on the Perris block, and thin to relatively thick sections of nonmarine, mainly Quaternary sediments discontinuously cover the basement rocks. Typically the broad valley areas are infilled with younger alluvial outwash derived from the surrounding mountain ranges. The proposed project site is relatively flat at approximately 1,120 feet elevation above sea level, and is underlain by Quaternary age alluvial sediments. The site, as well as much of southern California, is within a highly active seismic region.

7.15.1.1 Regional Geology

The regional geology is relatively complex and is shown on Figure 7.15-2 (also see legend in Table 7.15-1). The SGGS is located in the Peninsular Ranges Province that extends over 870 miles from just south of the San Gabriel and Santa Monica mountains, (approximately the length of the Cucamonga/Sierra Madre/Malibu Coast Fault zones) and the Channel Islands into Mexico, where it forms the Baja California peninsula. The province extends to the west offshore to the continental margin (Patton Escarpment), and the eastern boundary is the west side of the Salton Trough. Within the province, the overall physiography and both Cenozoic and Mesozoic structural features are dominantly oriented northwest parallel to the coast. With the exception of the Los Angeles Basin and along major fault zones, the province has undergone only relatively minor internal deformation during the Tertiary. This relatively low level of deformation contrasts strongly with the pervasive Tertiary deformation in the Transverse Ranges, especially the San Gabriel Mountains. In the area of the proposed project, the Peninsular Ranges Province can be divided into a series of fault-bounded blocks, each of which has a set of uniform characteristics internally.

The formation of the current northwest trending landscape within the Peninsular Ranges Province is the result of continuing movement along a series of generally northwest trending faults paralleling the San Andreas Fault. The historically active San Andreas Fault is located to the northeast of the site and forms

Table 7.15-1
Legend for Regional Geology Map

Quaternary Surficial Deposits		
Qaf	Artificial fill (late Holocene)	Sand, gravel, and bedrock from pits, quarries, and excavations related to construction, mining, or quarrying activities; mapped primarily where materials are placed for construction of highways, canals, railway grades, dams, and water catchment basins.
Qf	Very young alluvial-fan deposits (late Holocene)	Unconsolidated to slightly coherent, essentially undissected deposits of sand, gravel, and boulders that form active and recently active parts of alluvial fans. Clasts typically angular to subrounded, rarely rounded. Deposits generally coarsen toward heads of fans. Relative abundance of clast sizes varies greatly depending on setting, size of drainage area, and sediment source. At most places, unit lacks soil development, but on south side of San Bernardino Mountains, locally is capped by weak A/AC soils. Surfaces typically cut by braided streams, but deposition exceeds dissection. Where subdivision of Qf deposits is possible, subunits are distinguished from one another by relative position in local terrace riser succession, by local superposition, or by relative dissection. Includes:
Qf_2	Very young alluvial-fan deposits, Unit 2	Unconsolidated to loosely compacted alluvial-fan deposits. Essentially undissected, but surface typically cut by anastomosing network of channels. Size, shape, and distribution of clasts similar to that of unit Qf. Distinguished in most cases as fans built out on Qf_1 sediments, and to some degree as fans relatively less dissected than, or emanating from channels cut into, Qf_1 sediments. Appearance from place to place differs greatly; primarily dependent on sediment source, steepness of source area and fan location, and distance from mountain front
Qyf	Young alluvial-fan deposits (Holocene and late Pleistocene)	Unconsolidated to moderately consolidated silt, sand, pebbly cobbly sand, and bouldery alluvial-fan deposits having slightly to moderately dissected surfaces. Young alluvial-fan deposits, including subunits, constitute most widespread, and probably greatest in terms of sediment volume, of all Quaternary units. Forms large and small fans throughout quadrangle. Close to mountains, unit typically contains large proportion of cobbles and boulders. Intermediate and distal parts of large fans are mainly pale-brown, mixed silt to medium-grained sand, containing sparse, coarse-grained sand and pebble lenses. Except where coarser-grained lenses are present, stratification is obscure. Clast compositions, especially in upper third of fans, reflect bedrock source areas and clast compositions of nearby older Quaternary units. In San Bernardino Mountain area, fans emanating from areas underlain by deeply weathered Cretaceous granitic rocks are relatively fine grained and contrast with coarser-grained fans emananating from areas underlain by Triassic and older rocks. Includes from youngest to oldest:
Qyf_5	Young alluvial-fan deposits, Unit 5 (late Holocene)	Unconsolidated to slightly consolidated coarse-grained sand to bouldery alluvial-fan deposits having slightly dissected to essentially undissected surfaces. Notably finer grained in some parts, especially in distal parts of fans. Braided stream pattern on surfaces of fans that is related to deposition is relatively unmodified. Includes large, well formed fan emanating from Lytle Creek drainage. Parts of unit subsequently redistributed by conventional stream flow, especially in distal areas. Fans of Qyf_5 sequence are younger than Qyf_4 fans based mainly on relative position in terrace riser sequence and on superposition and overlap relations of adjacent fans

Table 7.15-1 Legend for Regional Geology Map		
Quaternary Surficial Deposits		
Qyf_4	Young alluvial-fan deposits, Unit 4 (late Holocene)	Unconsolidated to slightly consolidated silt, sand, and coarse-grained sand to bouldery alluvial-fan deposits having slightly to moderately dissected surfaces. Typically braided stream pattern on surfaces of fans related to deposition is only slightly modified.
Qyf_1	Young alluvial-fan deposits, Unit 1 (early Holocene and late Pleistocene)	Slightly to moderately consolidated silt, sand, and coarse-grained sand to bouldery. Has well-developed S5 soils. Appears as alluvial-fan deposits having moderately dissected surfaces. Form major fill that was deposited throughout San Bernardino Valley region during transition between late Pleistocene and Holocene (McFadden and Weldon, 1987; Morton and Matti, 1987). Fans contain a much higher percentage of boulders than on north side of San Bernardino Mountains, east of the Mojave River.
Qye	Young eolian deposits (Holocene and late Pleistocene)	Silt and medium- to fine-grained sand. Slightly dissected by thin, discontinuous, poorly developed stream channels oriented mainly parallel to dune crests.

the boundary between the North American and Pacific tectonic plates. Continuing tectonic interactions along this plate boundary are responsible for continued folding, as well as large magnitude earthquakes that occur along the San Andreas and other parallel faults within the province. The Perris block is a rectangular-shaped block that has low relief. It is bounded on the north and east by the San Jacinto Fault, on the north by the Cucamonga Fault; on the southwest by the Chino Fault; and on the south by the Elsinore Fault. As shown on Figure 7.15-1, the Perris block contains the proposed project site.

The Perris block consists of two distinct parts, a northern and a southern part. The proposed project site is located in the northern part of the block that consists of the largely alluvial valley area of the Santa Ana River. Most of the area north of the Santa Ana River is covered by late Pleistocene and Holocene alluvial fan deposits, which emanate from uplift of the high-standing San Gabriel Mountains. These fans consist of boulder deposits in the proximal parts and grade to sandy deposits in the distal parts.

The proposed project site is located on Pleistocene alluvial fan deposits and recent Holocene wash deposits up to 1,000 feet in depth. The proposed project site is located approximately midway up broad coalescing, gently south-sloping alluvial fans at the base of the San Gabriel Mountains, which rise sharply to the north of the site to elevations over 10,000 feet.

7.15.1.2 Local Geology

The study area for geologic hazards and resources extends to a 2-mile radius around the proposed project site and associated linear facilities. The proposed project site is on unconsolidated sedimentary deposits typical of the lower proximal part of an alluvial fan. The deposits are characterized by sands and gravels with interbedded layers of silts and clays. The deposits overlay igneous and metamorphic Mesozoic crystalline basement. Groundwater in the vicinity occurs at a depth of approximately 700 to 800 feet and flows south to southwest. The thickness of the sedimentary deposits in the vicinity of these basins is approximately 900 to 1,000 feet. Figure 7.15-3 shows the local geology within a 2-mile radius of the proposed project site.

Structure

The geological structure of the study area is dominated by basement metamorphic and igneous rocks of the San Gabriel Mountains to the north and the alluvial fan deposits that emanated from the mountains. Historically, the alluvial fan complex extended much further south from the San Gabriel Mountains than the present-day fans. These older fans, now represented only by discontinuous lag gravels, covered the Jurupa Mountains and extended south of Riverside. The southern distal parts of this fan complex were flanked by an ancestral Santa Ana River, well south of the present day location of the river (Morton and Matti, 1989). Morton and Matti (1989) interpret the Perris block to have been elevated concurrent with offset on the San Jacinto Fault, resulting in compression of the Perris block and the eastern San Gabriel Mountains. Attendant to this compression, a section of the Perris block was down-dropped along a fault.

Stratigraphy

Stratigraphically, the study area is underlain by 900 to 1,000 feet of unconsolidated alluvial fan deposits of Quaternary age (up to 2 million years old). These materials are underlain by basement granitic and metamorphic rock. A generalized geologic description of the units follows.

Alluvial Deposits

Very young alluvial fan deposits (late Holocene): Unconsolidated to slightly coherent, essentially undissected deposits of sand, gravel, and boulders that form active and recently active parts of alluvial fans. Essentially undissected, but the surface is typically cut by an anastomosing network of channels. The size, shape, and distribution of clasts can be distinguished as fans built out on other very young fan sediments. The appearance from place to place differs greatly and is primarily dependent on sediment source, steepness of source area and fan location, and distance from mountain front.

Old alluvial fan deposits (late to middle Pleistocene): Moderately- to well-consolidated silt, sand, and gravel. Subunits are distinguished on basis of soil-profile development, degree of dissection, and relative position in local terrace-riser succession. Alluvial fan deposits of primarily sand- to boulder-sized clasts are moderately consolidated and slightly to moderately dissected.

Basement Rocks

Mylonitized tonalite (Cretaceous): Gneissic and mylonitic tonalite; mylonitic deformation is irregularly and discontinuously distributed but is found throughout the unit.

Diorite (Cretaceous): Diorite; forms discontinuous masses near contacts between tonalite and granulitic rocks. Medium- to coarse-grained; typically has foliation that ranges from faint to well developed.

Granulitic gneiss, mylonite, and cataclasite, retrograde (Proterozoic): Prograde granulitic gneiss that is largely retrograde to amphibolite and greenschist grade mylonite and cataclasite.

7.15.1.3 Regional Seismotectonic Setting and Seismicity

Southern California is within the boundary between the North American and Pacific plates. The relative motion between these two plates has been determined to be primarily horizontal at a rate of about 28 millimeters per year (DeMets et al., 1987). On a broad scale, the North American-Pacific plate boundary in California is a transform fault that extends from the Gulf of California to Cape Mendocino. The San Andreas Fault and the transform plate boundary end to the north at the Mendocino Triple Junction in northernmost California.

Whereas, in northern California, the relative plate motion is concentrated near the San Andreas Fault, the San Andreas Fault in southern California makes a notable bend within the Transverse Ranges. From this point southward, the plate motion is spread over a wide area of deformation, encompassing normal, strike-slip, and reverse faults. While the majority of the plate motion appears accommodated by the San Andreas Fault itself, the rest of the motion is distributed among a dozen or so other major faults (Weldon and Humphreys, 1986). These other major fault zones include the Eastern Mojave Shear Zone (a series of faults east of the San Andreas, responsible for the 1992 Landers and the 1999 Hector Mine Earthquakes); the northwest-trending San Jacinto, Whittier-Elsinore, and Newport-Inglewood Fault Zones; and several east-trending thrust faults along the southern boundary to the Transverse Ranges. The diffuse deformation pattern leads to the high level of seismic activity and to a complicated setting.

The seismic sources that may significantly affect the SGGS site include the active faults of the San Andreas, San Jacinto, and Elsinore Fault Zones and the Cucamonga Fault. The historic record indicates that moderate to large earthquakes have occurred along these faults, resulting in moderate to strong levels of shaking.

As described above, the proposed project site lies within the active fault-bounded Perris block that is dominated by the active San Andreas Fault System. The San Andreas Fault Zone is a northwest-oriented, right-lateral strike-slip fault zone, which also includes the San Jacinto Fault Zone (Sharp, 1967) and Elsinore Fault Zone (Hull and Nicholson, 1992; Langenkamp and Combs, 1974). Less well known are the compressional and rare extensional faults that are a result of displacement on the right-lateral strike-slip faults.

The neotectonic San Andreas Fault is a continuous fault that has well-expressed physographic development in the area. Both the San Jacinto and Elsinore Fault Zones consist of en echelon faults that have formed a series of extensional basins and compressional uplifts (Hull, 1990; Kennedy, 1977; Morton and Matti, 1993; Sharp, 1967; Weber, 1976). In addition to the neotectonic San Andreas Fault are inactive older strands, principally the San Gabriel, Punchbowl, Cajon Valley, and the North Branch of the San Andreas in the San Bernardino Mountains. A major triangular-shaped (plan view) extensional basin, the San Bernardino Basin occupies the area between the San Andreas Fault and the San Jacinto Fault Zone in the San Bernardino Valley area. Because of Quaternary cover, structures between the San Gabriel Mountains and the Jurupa Mountains are poorly understood, including the informally named Fontana seismic zone and the nature and location of the boundary between the Peninsular Ranges and San Gabriel Mountains assemblages.

The angular discordance between the San Jacinto and the San Andreas Fault Zones results in compression and movement on the Cucamonga Fault Zone along the south margin of the eastern San Gabriel Mountains as well as the uplift of the eastern San Gabriel Mountains (Morton and Matti, 1993).

The northern part of the San Jacinto structural basin formed at a right step between the Claremont Fault on the east and the Casa Loma Fault on the west. The San Jacinto structural basin is the site of rapid subsidence, both long-term tectonic subsidence and more recent subsidence due to groundwater withdrawal (e.g., Morton, 1977). Both the Casa Loma and Claremont Faults of the San Jacinto Fault Zone display youthful fault features, and are considered to have been the source of major earthquakes in the early part of the 20th century.

The Elsinore Fault Zone consists of a complex assemblage of right-stepping and left-stepping en echelon faults. Movements on these faults have produced a series of extensional basins that in aggregate result in an elongate, composite, structural trough. The trough includes numerous minor compressional uplifted domains (Hull, 1990; Kennedy, 1977; Weber, 1976), some of which separate the constituent extensional basins. The largest of these extensional basins, the Elsinore structural basin, is largely filled by Lake Elsinore. In the vicinity of Corona, about 20 miles south of the proposed project site, the Elsinore Fault

Zone either branches into or intersects two independent faults: the Whittier Fault, which has a more westerly strike, and the Chino Fault, which continues for about 9.3 miles with the same strike as the Elsinore Fault. The junction of these faults is obscured beneath young alluvium.

There are three large reverse fault systems in the area: the Cucamonga-Sierra Madre Fault system bounding the south edge of the San Gabriel Mountains, the reverse faults bounding the north edge of the San Bernardino Mountains, and the reverse faults that project into the eastern part of the San Bernardino quadrangle from the Santa Ana Canyon area of the San Bernardino Mountains. The Cucamonga and Sierra Madre Faults are seismically active, north dipping reverse or thrust faults that in many places fault crystalline bedrock over Quaternary deposits. Locally, the Cucamonga Fault has well formed south facing scarps developed in young Quaternary deposits (Eckis, 1928; Morton, 1976; Morton and Matti, 1987).

The faults bounding the north side of the San Bernardino Mountains are south dipping reverse faults that in many places show high, well-developed scarps, which are formed in older Quaternary deposits and are moderately degraded (Meisling, 1984; Meisling and Weldon, 1989; Miller, 1987). Where they are developed in the San Bernardino quadrangle, the faults that emanate from the Santa Ana Canyon area are relatively steeply north dipping and, although part of a seismically active zone, do not have recognizable scarps, probably because the very steep slopes in the area do not allow their preservation. Eastward, these faults coalesce into a single large and a few small north dipping reverse faults.

A much older fault, the Vincent Thrust of probable early Tertiary age (Grove et al., 2003), is well exposed in the high parts of the eastern San Gabriel Mountains and poorly exposed but well located in the Crafton Hills located southeast of the proposed project site. It typically is gently dipping to subhorizontal but in places is near vertical, especially near younger faults that disrupt it. The fault separates Pelona Schist (Kpu) in the lower plate from highly deformed metamorphic and granitic rocks in the upper plate.

Patterns of historical seismicity (Figure 7.15-4) and microearthquakes in the region show that the right-stepping and left-stepping en echelon faults, thrust faults, and reverse faults are active. Slip rates along segments of the San Andreas Fault Zone in Southern California range between 24 to 34 millimeters per year (mm/yr). For segments of the San Jacinto Fault Zone in the area, slip rates are approximately 4 to 20 mm/yr, and for the Elsinore Fault Zone are 4 to 5 mm/yr. The reverse Cucamonga Fault has a slip rate of 5 mm/yr (Cao et al., 2003).

Significant Faults

Southern California as a region is considered very seismically active, largely due to the abundance of active faults. The state of California, under the guidelines of the Alquist-Priolo Earthquake Fault Zoning Act (Hart and Bryant, 1997), considers a fault segment active if it has experienced a displacement in the historical record (last 200 years) or during the Holocene (last 11,000 years). A fault segment is considered potentially active if there is evidence of a displacement during the Late Quaternary (last 700,000 years) or the Quaternary (last 1.6 million years) (Jennings, 1994; Hart, 1994).

The 53 active faults within 75 miles of the proposed project site are listed in Table 7.15-2. Table 7.15-2 also provides the estimates of the maximum earthquake for each fault and the closest distance from each fault to the SGGS (Blake, 2004). Maximum earthquake magnitude (M_{max}) estimates are based on EQFAULT, a computer program for the deterministic prediction of peak horizontal acceleration from digitized California Faults. Figure 7.15-5 shows the location of the SGGS in relation to the major Quaternary Faults in the site region.

Table 7.15-2
Major Faults in the Vicinity of the Proposed San Gabriel Generating Station

Fault Name	Approximate Distance mi (km)	Maximum Earthquake Magnitude (M_w)	Peak Site Acceleration (g)	Estimated Site Intensity Modified Mercalli
Cucamonga	7.8 (12.5)	7.0	0.408	X
San Jacinto-San Bernardino	8.3 (13.3)	6.7	0.285	IX
San Jose	9.9 (16.0)	6.5	0.261	IX
Sierra Madre	12.3 (19.8)	7.0	0.275	IX
San Andreas-San Bernardino	13.2 (21.2)	7.3	0.275	IX
San Andreas-Southern	13.2 (21.2)	7.4	0.291	IX
Chino-Central Ave. (Elsinore)	13.5 (21.7)	6.7	0.209	VIII
San Andreas-Mojave	15.2 (24.5)	7.1	0.213	VIII
San Andreas-1857 Rupture	15.2 (24.5)	7.8	0.322	IX
Cleghorn	15.5 (25.0)	6.5	0.134	VIII
San Jacinto-San Jacinto Valley	17.5 (28.2)	6.9	0.159	VIII
Elsinore-Glen Ivy	17.6 (28.4)	6.8	0.147	VIII
Whittier	17.6 (28.4)	6.8	0.147	VIII
North Frontal Fault Zone (West)	20.9 (33.6)	7.0	0.151	VIII
Elysian Park Thrust	22.0 (35.4)	6.7	0.114	VII
Clamshell-Sawpit	22.6 (36.3)	6.5	0.095	VII
Raymond	28.1 (45.3)	6.5	0.070	VI
Elsinore-Temecula	32.7 (52.7)	6.8	0.070	VI
Compton Thrust	33.2 (53.5)	6.8	0.070	VI
Verdugo	33.7 (54.2)	6.7	0.064	VI
Newport-Inglewood (L.A. Basin)	39.6 (63.8)	6.9	0.060	VI
Hollywood	40.4 (65.0)	6.4	0.039	V
Helendale-S. Lockhardt	40.8 (65.6)	7.1	0.068	VI
Newport-Inglewood (Offshore)	41.1 (66.2)	6.9	0.057	VI
San Jacinto-Anza	42.6 (68.6)	7.2	0.070	VI
North Frontal Fault Zone (East)	42.8 (68.9)	6.7	0.046	VI
San Gabriel	45.8 (73.7)	7.0	0.054	VI
Pinto Mountain	46.2 (74.3)	7.0	0.054	VI
Sierra Madre (San Fernando)	46.3 (74.5)	6.7	0.041	V
Palos Verdes	48.5 (78.1)	7.1	0.055	VI
Santa Monica	50.6 (81.5)	6.6	0.033	V
Northridge (E. Oak Ridge)	52.1 (83.8)	6.9	0.041	V
Lenwood-Lockhart-Old Woman Springs	53.6 (86.3)	7.3	0.057	VI
Johnson Valley (Northern)	57.2 (92.0)	6.7	0.031	V
Elsinore-Julian	57.5 (92.6)	7.1	0.044	VI
Malibu Coast	57.6 (92.7)	6.7	0.030	V
Santa Susana	58.0 (93.4)	6.6	0.027	V
Coronado Bank	61.3 (98.7)	7.4	0.053	VI
San Andreas-Coachella	61.7 (99.3)	7.1	0.040	V
Landers	61.9 (99.6)	7.3	0.048	VI
Holser	62.6 (100.8)	6.5	0.023	IV
Gravel Hills-Harper Lake	63.9 (102.9)	6.9	0.032	V
Emerson So.-Copper Mtn	64.3 (103.5)	6.9	0.032	V
Burnt Mtn.	64.3 (103.5)	6.4	0.020	IV
Eureka Peak	64.9 (104.5)	6.4	0.020	IV
Rose Canyon	66.7 (107.4)	6.9	0.030	V
Anacapa-Dume	67.7 (108.9)	7.3	0.039	V
Calico-Hidalgo	69.9 (112.5)	7.1	0.034	V
San Andreas-Carrizo	70.1 (112.8)	7.2	0.037	V
Blackwater	70.8 (113.9)	6.9	0.028	V
Oak Ridge (Onshore)	71.3 (114.8)	6.9	0.026	V
San Jacinto-Coyote Creek	73.0 (117.5)	6.8	0.025	V
Simi-Santa Rosa	74.3 (119.6)	6.7	0.021	IV

Source: Blake, 2004

The proposed project site is located near two of California's most active faults, the San Andreas and San Jacinto Faults (Figure 7.15-5). Both of these faults in the vicinity of the proposed project site have the potential to generate an earthquake in the near future at a maximum magnitude (M_w) of 7.8 and 6.9, respectively. The Cucamonga Fault is located even closer to the site and has the potential to generate a Magnitude (M) 7.0 earthquake. Also, much of the region is underlain by a series of unmapped blind thrust faults that have no surface trace and can generate earthquakes of M 6.8 (Working Group, 1995). The City of Rancho Cucamonga has adopted an earthquake special study zone on the City's General Plan Geotechnical Hazard Map for the area around the Red Hill Fault (City of Rancho Cucamonga, 2001b). The proposed project site is not within this zone. Significant active faults in the vicinity of the proposed project site are described below.

San Andreas Fault Zone: The San Andreas Fault is the principal boundary between the Pacific and North American Plates and is the controlling structure relative to the seismic hazard for Southern California. The San Andreas Fault is an approximately 750-mile-long, right lateral, strike-slip fault that has been the source of two M > 7.75 historic earthquakes in California (the 1857 Fort Tejon earthquake and the 1906 San Francisco earthquake). The last major earthquake on the southern San Andreas Fault was the 1857 M_w 7.9 Fort Tejon quake. This is the largest earthquake that has been reported in California, warranting a M_w earthquake of 7.8 and a ground acceleration of as much as 0.32g (rounded up, g = acceleration due to gravity) in the vicinity of the epicenter. A recurrence interval of 167 years for this section of the fault has been estimated (Working Group, 1995). Geologic and geodetic data indicate that the slip rate on segments of the San Andreas Fault in the vicinity ranges from 24 to 34 mm/yr (Cao et al., 2003). The closest approach of the San Andreas Fault to the SGGS is 13.2 miles.

San Jacinto Fault Zone: The San Jacinto Fault Zone consists of a series of closely spaced faults that form the western margin of the San Jacinto Mountains. The fault zone extends from its junction with the San Andreas Fault in San Bernardino, southeasterly toward the Brawley area, where it continues south of the international border as the Imperial Fault. The San Jacinto Fault Zone has a high level of historical seismic activity, with at least 10 moderate (M 6 – 7) earthquakes having occurred on this fault zone between 1890 and 1986. Offset across this fault is predominantly right-lateral similar to the San Andreas Fault. A M_w earthquake of 6.9 and a ground acceleration of as much as 0.285g in the vicinity of the epicenter is projected for the fault. Geologic and geodetic data indicate that the slip rate on segments of the San Jacinto Fault in the vicinity of the proposed project site ranges from 4 to 20 mm/yr (Cao et al., 2003). The closest approach of the San Jacinto Fault to the proposed project site is 8.3 miles.

Cucamonga Fault Zone: The Cucamonga Fault Zone is a youthful element of the Transverse Ranges family of thrust faults (Morton and Matti, 1987). It is the eastward extension of the Sierra Madre Fault and one of the closest known active faults to the proposed project site. The Cucamonga Fault Zone is composed of a series of east-west trending, north dipping reverse faults that displace Holocene sediments. Northerly to southerly, this frontal fault zone bounds the southern margin of the San Gabriel Mountains to the southern margin of the San Bernardino Mountains, disrupting the flanking Quaternary alluvial fans (Morton, 1976). The alluvial fan material is composed of modern stream channels and alluvial fan sediments associated with the Upper Santa Ana River Valley. A M_w earthquake of 7.0 and a ground acceleration of as much as 0.408g in the vicinity of the epicenter is projected for the fault. Geologic and geodetic data indicate that the slip rate on segments of the Cucamonga in the vicinity of the proposed project site ranges from 5 mm/yr (Cao et al., 2003). The closest approach of the Cucamonga Fault to the proposed project site is 7.8 miles.

Red Hill-Etiwanda Fault: The Red Hill-Etiwanda Fault is a potentially active fault inferred to curve around the southern portion of Red Hill and to extend northeast just south of Highland Avenue. Groundwater data have been used to infer the Red Hill Fault Zone as a complex tectonic system of faults with a possible reverse thrust component. The fault has been postulated as a branch of the Cucamonga

Fault. The closest approach of the Red Hill-Etiwanda Fault to the proposed project site is about 5.5 miles (City of Rancho Cucamonga, 2001b).

San Jose Fault Zone: The San Jose Fault is a northeast-trending, strike-slip fault exhibiting left lateral movement that has been associated with the Walnut Creek Fault. The fault is traceable for approximately 14 miles, from just south of the San Gabriel Mountains to the San Jose Hills. Some compression and thrusting near the northern end of the San Jose Hills occurs where the Walnut Creek Fault turns more east-west. In addition to left-slip movement, the fault has displayed significant uplift, as evidenced by the presence of the San Jose Hills. Both the 1988 and 1990 Upland earthquakes are believed to have occurred on the San Jose Fault. A M_w earthquake of 6.5 and a ground acceleration of as much as 0.261g in the vicinity of the epicenter is projected for the fault. Geologic and geodetic data indicate that the slip rate on segments of the San Jose in the vicinity of the proposed project site ranges from 0.5 mm/yr (Cao et al., 2003). The closest approach of the San Jose Fault to the proposed project site is 9.9 miles.

Potentially Active Faults: The California Geological Survey considers a number of faults in the vicinity of the proposed project site as potentially active. Potentially active faults are those that have had seismic activity between 11,000 and 2 million years. The faults are not included in the Alquist-Priolo Special Study Zones. In the study area, the traces of potentially active faults are hidden by Quaternary alluvial materials and have been identified primarily through the evaluation of geophysical and water table data. The Rialto-Colton Fault is a potentially active fault located approximately 6 miles east of the proposed project site. The location, extent, and hydrologic characteristics of the Rialto-Colton Fault, which has been defined as the hydrologic boundary between the Rialto-Colton and Chino Basins, is not precisely known. The Rialto-Colton Fault has experienced both right-lateral, strike-slip, and normal fault motion that has offset basement rock. In study area, the fault extends to within a few yards of the surface and acts as a groundwater barrier, suggesting that there has been recent activity (Anderson, 2000; Woolfenden and Kadhim, 1997). Therefore, the Rialto-Colton Fault is considered to have a high potential for ground surface rupture.

Historical Seismicity

The most frequent historical seismicity in Southern California is largely associated with the San Andreas Fault System, although infrequent moderate magnitude earthquakes occur outside of this system. Several of the faults within the San Andreas system have produced large magnitude historical events that caused damage to buildings and structures in the region. As a number of the earthquakes occurred before modern instruments were developed, the magnitude and distribution of damage can only be surmised from written historical documents. Figure 7.15-4 shows historic earthquakes in the site vicinity that occurred in the period from 1864-2006.

There have been approximately 56 historical earthquakes of M 5.5 or greater in the Southern California region. Historically, there have also been several major earthquakes in the region such as the 1857 M_w 7.9 Fort Tejon and the 1982 M_w 7.8 Imperial Valley earthquakes. Earthquakes of this magnitude can pose significant ground-shaking hazard to the study area. The following paragraphs discuss a few of these historic earthquakes that are considered of relevance to the proposed project site.

October 16, 1999, Hector Mine Earthquake. This M_w 7.1 earthquake was centered in such a remote part of the Mojave Desert that, instead of being named for the nearest town or the community that suffered the greatest damage, it was named after the closest spot in the list of reference points used by the Southern California Seismic Network: the Hector Mine, an open pit quarry 14 miles northwest of the epicenter. This was the largest earthquake to strike the area since the M 7.3 Landers earthquake of June 28, 1992.

The location of the earthquake was so remote that it caused relatively negligible damage for a magnitude M_w 7.1 earthquake. The 25-mile surface rupture along the Lavic Lake Fault and central section of the

Bullion Fault was located entirely within the boundaries of the Twentynine Palms Marine Corps Base, and crossed neither paved roads nor structures (unlike the Landers rupture of 1992). Location: 34.59N 116.27W (SCEC, 2007).

January 17, 1994, Northridge Earthquake. The M_w 6.7 earthquake occurred on a blind thrust fault (Northridge Thrust, also known as Pico Thrust) and produced the strongest ground motions ever instrumentally recorded in an urban setting in North America. Damage was widespread, sections of major freeways collapsed, parking structures and office buildings collapsed, and numerous apartment buildings suffered irreparable damage. Damage to wood-framed apartment houses was very widespread in the San Fernando Valley and Santa Monica areas, especially to structures with “soft” first floor or lower-level parking garages. The high accelerations, both vertical and horizontal, lifted structures off of their foundations and/or shifted walls laterally. Location: 34 12.80’ N, 118°32.22’ W (SCEC, 2007).

June 28, 1992, Landers Earthquake. The M_w 7.3 quake was preceded a few months earlier by the Joshua Tree M 6.3 earthquake on April 22 and followed by the Big Bear M_w 6.4 earthquake at 8:05 a.m. later that day. A robust aftershock sequence followed and consisted of thousands of tremors, including 143 quakes registered as M 4.0 or stronger—19 of which measured M 5.0 or stronger. The most recent moderate aftershock was the Joshua Tree M 5.0 earthquake on May 14, 1999.

Vigorous shaking was felt 100 miles away in Los Angeles, and the quake was felt as far away as Central California and Las Vegas, Nevada. One person was killed, 25 were seriously injured, and another 372 were treated for some sort of earthquake-related injuries. The total property damage value was on the order of $56 million and included collapsed buildings, ruptured utility lines, and widespread nonstructural damage (Seismo-Watch.com, 2007).

Three items of notable interest came out regarding this quake: (1) the quake ruptured disconnected surface traces of several known faults (Johnson Valley, Landers, Homestead Valley, Emerson, and Camp Rock) and several other unknown faults for a distance of 53 miles; (2) the displacement was two to three times larger than generally anticipated for these faults, with maximum horizontal offsets of 15-20 feet across a zone 30-60 feet wide; and as a consequence, (3) the magnitude was much larger for these individual faults than envisioned by seismologists and geologists. Location: 34 13’ N, 116 26’ W (SCEC, 2007).

June 28, 1992, Big Bear Earthquake. While technically an “aftershock” of the Landers earthquake (indeed, the largest aftershock), the M_w 6.4 Big Bear earthquake occurred more than 24.8 miles west of the Landers rupture, on a fault with a different orientation and sense of slip than those involved in the main shock—an orientation and slip that could be considered “conjugate“ to the faults that slipped in the Landers rupture. The Big Bear earthquake rupture did not break the surface; in fact, no surface trace of a fault with the proper orientation has been found in the area. However, the earthquake produced its own set of aftershocks, and from these, the fault geometry is known—left-lateral slip on a northeast-trending fault.

Following the Landers mainshock by three hours (it occurred while TV news coverage of the Landers earthquake was being broadcast live from Caltech), the Big Bear earthquake caused a substantial amount of damage in the Big Bear area but fortunately claimed no lives. Landslides triggered by the jolt blocked roads in the San Bernardino Mountains, which aggravated the cleanup and rebuilding process. Location: 34° 12’ N, 116° 49.6’ W (SCEC, 2007).

April 22, 1992, Joshua Tree Earthquake. Preceded by a M 4.6 foreshock, the M_w 6.1 Joshua Tree earthquake raised some alarms due to its proximity to the San Andreas Fault. A San Andreas Hazard Level B was declared following this quake, meaning that a 5 percent to 25 percent chance existed for an even larger earthquake to occur along the San Andreas Fault within 3 days. That did not happen, but about two months and 6,000 aftershocks later, the Landers earthquake broke the surface of the Mojave

Desert in the largest earthquake to hit Southern California in 40 years. This event showed that the concern caused by the Joshua Tree earthquake was warranted, although not in quite the same manner as anticipated.

The aftershocks of the Joshua Tree earthquake suggested that the fault that slipped in the shock was a north-northwest-trending, right-lateral, strike-slip fault at least 9.3 miles long. From this and the location of the shocks, one can infer that the Eureka Peak Fault may have been the causative structure responsible for this earthquake.

Damage caused by the Joshua Tree earthquake was slight to moderate in the communities of Joshua Tree, Yucca Valley, Desert Hot Springs, Palm Springs, and Twentynine Palms. Thirty-two people had to be treated for minor injuries. Though somewhat forgotten in the wake of the Landers earthquake, the Joshua Tree quake was a significant event on its own and was felt as far away as San Diego, Santa Barbara, Las Vegas, Nevada, and even Phoenix, Arizona. Location: 33°57.6' N, 116°19' W (SCEC, 2007).

7.15.1.4 Geologic Hazards

The following sections discuss potential geologic hazards that may occur at the proposed SGGS site.

Surface Fault Rupture

No faults are mapped at the proposed project site, and there are no faults zoned under the Alquist-Priolo Act within a 2-mile radius of the site. The closest fault zone to the site that could produce surface fault rupture and has demonstrated Holocene activity is the Cucamonga Fault, about 7.8 miles to the northwest.

The Alquist-Priolo Earthquake Fault Zoning Act requires the California Geological Survey (CGS) to designate faults considered active or potentially active, and to establish zones within which studies are required for structures involving human occupancy. Based on the lack of active faulting and the absence of Alquist-Priolo-zoned faults in the study area, the hazard from ground rupture is considered negligible.

Earthquake Ground Shaking

The most significant geologic hazard at the proposed project site is strong ground shaking due to an earthquake. The site has experienced at least moderate ground motions in the past and will do so in the future. Blake (2004) estimates that the ground shaking of an M 7.0 earthquake along the Cucamonga Fault could produce a peak bedrock acceleration of up to 0.41 g in the vicinity of the SGGS. This is the maximum credible earthquake (MCE) event with ground motions associated with a 2,500-year mean return period or a 2 percent probability of exceedance in 50 years. This would affect the proposed project site.

The published CGS Earthquake Shaking Potential Map for Southern California, which is presented as Figure 7.15-6 in this document, shows the relative level of ground-shaking intensity anticipated at the proposed project site. Figure 7.15-7 shows ground motions with a 10 percent probability of being exceeded within the next 50 years are estimated at about 0.55 g at the site (Campbell and Bozorgnia, 1997, rev. 2003).

Liquefaction

Liquefaction is the phenomenon during which loose, saturated, cohesionless soils temporarily lose shear strength during strong ground shaking. Significant factors known to affect the liquefaction potential of soils are the characteristics of the materials such as grain size distribution, relative density, degree of saturation, the initial stresses acting on the soils, as well as the characteristics of the earthquake, such as the intensity and duration of the ground shaking. Liquefaction typically occurs when the water table is shallow (generally less than 40 feet below ground surface) and the soils are predominantly granular and unconsolidated. The potential for liquefaction increases as the groundwater approaches the surface. Groundwater in the vicinity of the proposed project occurs at a depth of approximately 700 to 800 feet. Accordingly, the potential for liquefaction at the site is considered negligible.

Seiches and Tsunami

Seiches are oscillations in an enclosed body of water (e.g., lake, pond, or water tank) that may be caused by an earthquake. The proposed project will include a stormwater detention basin and water tanks. A 4-acre-foot reservoir used to balance and recirculate process water to the existing plant is located in the northeast corner of the EGS site. The degree of damage that would occur in the event of a seiche would be less than significant.

Tsunamis are seismic seas waves that can be triggered by submarine earthquakes, landslides, or volcanic eruptions. No large bodies of water are adjacent to the proposed project site. Because the site is more than 40 miles from the Pacific Ocean, the occurrence of a tsunami off the coast of California would have no impact on the proposed project site.

Mass Wasting and Slope Stability

Slope instability depends on steepness of the slope, underlying geology, surface soil strength, and pore pressures in the soil. Because the proposed project site is relatively flat, the potential for direct impact from landslides at the site is considered nonexistent. A slope stability map from the City of Rancho Cucamonga General Plan (City of Rancho Cucamonga, 2001a) shows the site area with slope gradients of less than 10 percent and being an area of low landslide potential. The lack of significant slopes on or near the site indicates that the hazard from slope instability, both landslides and debris flows, is negligible.

Subsidence

Subsidence of the land surface can be attributed to natural phenomena, e.g., tectonic deformation, consolidation, hydrocompaction, collapse of underground cavities, oxidation of organic-rich soils, or rapid sedimentation, as well as by the activities of man, e.g., the withdrawal of groundwater or hydrocarbons. Most of the physical conditions responsible for a real land subsidence are not known to exist at the proposed project site. Subsidence caused by groundwater withdrawals is not expected to be a significant problem at the proposed project site; however, future changes in groundwater pumping or development of hydrocarbon reserves in the region could theoretically affect the site.

Expansive Soils

Expansive soils are clay-rich soils that have the ability to shrink and swell with wetting and drying. The shrink-swell capacity of expansive soils can result in differential movement beneath foundations. The proposed project site and linear features are primarily underlain by sandy, granular soils with low expansion potential.

7.15.1.5 Geologic Resources

The proposed project will not cause a cumulative impact to geologic resources.

There are no known hydrocarbon resources within a 2-mile radius of the site. There are no aggregate mining operations within 2 miles of the proposed project site, and no mines within 2 miles of the site. The Day Creek alluvial fan located approximately 5.5 miles from the site is a significant local sand and gravel resource, which contains regionally significant deposits of aggregate materials that are considered potentially recoverable. The state has implemented a program whereby areas designated to be mineral deposit zones of regional and statewide significance are to be conserved where possible. Cities and counties are responsible for establishing policies and programs for the management of land uses in and around designated mineral deposit zones. Aggregate deposits available for recovery within the study area may be limited due to conflicts between urban development and typical surface mining operations (City of Rancho Cucamonga, 2001a).

7.15.2 Environmental Consequences

Potential impacts of the proposed project on the geologic environment and potential impacts of the environment on the project can be divided into those involving construction activities and those related to plant operation.

7.15.2.1 Construction

Overexcavation and recompaction will be required for the proposed project and in the temporary construction laydown areas in areas with loose unconsolidated soils. Site grading is not expected to result in significant adverse impacts to the geologic environment.

7.15.2.2 Operations

Seismically induced ground shaking presents a moderate hazard to the proposed project. This impact is potentially significant. Liquefaction and slope failure are not hazards at the proposed project site. No other geologic hazards with the potential to significantly affect the proposed project were identified. With implementation of the mitigation measures proposed in Section 7.15.4, all geologic hazards will be reduced to a less than significant level.

No significant impacts on the geologic environment are expected from the operation of the proposed plant.

7.15.3 Cumulative Impacts

Past, current, and potential future projects, including the proposed project, would not have a cumulatively significant impact on geologic resources, because there are no known developable natural resources occurring within the vicinity of the proposed project site. While the area lies in an area of known faults, no cumulative impacts are anticipated to the geologic environment as a result of cumulative projects or the proposed project, which will be designed to appropriate engineering design standards. Therefore, the proposed project would not contribute to a cumulatively significant impact, and cumulative impacts of the proposed project would be less than significant.

7.15.4 Mitigation Measures

This section discusses mitigation measures proposed by the Applicant that will be implemented to reduce project-related impacts from geologic hazards and to geologic resources.

> **GEO-1 Ground Shaking.** The proposed project may be subjected to moderate earthquake motions in the future. Thus, plant components will be designed and constructed at least to the seismic design requirements for ground shaking specified in the Uniform Building Code for Seismic Zone 4, and in accordance with the final recommendations of the project geotechnical engineer.

7.15.5 Laws, Ordinances, Regulations, and Standards

The proposed project will be constructed and operated in accordance with all laws, ordinances, regulations, and standards (LORS) applicable to geologic hazards and resources. Federal, state, and local LORS applicable to geologic hazards and resources are discussed and summarized in Table 7.15-3.

7.15.5.1 Federal

Acceptable design criteria for excavations and structures for static and dynamic loading conditions are specified by the Uniform Building Code (UBC), 1997.

7.15.5.2 State

For certain building design and requirement elements, the California Building Code, Title 24 (2001) would be superceded by the UBC as discussed above.

7.15.5.3 Local

According to the Rancho Cucamonga Planning and Building Department, no specific local LORS regarding geologic hazards would be applicable to the proposed activities at the proposed project site, other than the building permit review process. The City of Rancho Cucamonga has adopted an earthquake special study zone on the City's General Plan Geotechnical Hazard Map for the area around the Red Hill Fault. The proposed project site is not within this zone.

Table 7.15-3
Applicable Geologic Laws, Ordinances, Regulations, and Standards

Laws, Ordinances, Regulations, and Standards	Applicability	Administering Agency	AFC Section
Federal			
Uniform Building Code (UBC)	Design criteria for excavations and structures under static and dynamic loading conditions	San Bernardino County	7.15.5.1, Appendix C
State			
California Building Code, 2001	Superseded by UBC	N/A	7.15.5.2
Alquist Priolo Earthquake Fault Zoning Act; Title 14, Division 2, Chapter 8, Subchapter 1, Article 3, California Code of Regulations.	Identifies areas subject to surface rupture from active faults	California Geological Survey	7.15.1.4
The Seismic Hazards Mapping Act; Title 14, Division 2, Chapter 8, Subchapter 1, Article 10, California Code of Regulations.	Identifies non-surface fault rupture earthquake hazards, including liquefaction and seismically induced landslides	California Geological Survey	7.15.1.4
Regional			
None	N/A	N/A	7.15.5.3

Table 7.15-3
Applicable Geologic Laws, Ordinances, Regulations, and Standards

Laws, Ordinances, Regulations, and Standards	Applicability	Administering Agency	AFC Section
Local			
California Building Code, 2001	Superseded by UBC Acceptable design criteria for structures with respect to seismic design and loadbearing capacity	City of Rancho Cucamonga	7.15.5.3
Alquist Priolo Earthquake Fault Zoning Act; Title 14, Division 2, Chapter 8, Subchapter 1, Article 3, California Code of Regulations.	Identifies areas subject to surface rupture from active faults	City of Rancho Cucamonga	7.15.1.4
The Seismic Hazards Mapping Act; Title 14, Division 2, Chapter 8, Subchapter 1, Article 10, California Code of Regulations.	Identifies non-surface fault rupture earthquake hazards, including liquefaction and seismically induced landslides	City of Rancho Cucamonga	7.15.1.4
City of Rancho Cucamonga General Plan	Compliance with the safety element of the General Plan	City of Rancho Cucamonga	7.15.1.3

7.15.6 Involved Agencies and Agency Contacts

Issue	Agency/Address	Telephone
Geologic resources	California Geological Survey Headquarters/Office of the State Geologist 801 K Street, MS 12-30 Sacramento, CA 95814 cgshq@consrv.ca.gov	(916) 445-1825 (916) 445-5718 fax
Building Code	City of Rancho Cucamonga Department of Building and Safety 10500 Civic Center Drive Rancho Cucamonga, CA 91730 cityinfo@ci.rancho-cucamonga.ca.us	(909) 477-2710

7.15.7 Permits Required and Permit Schedule

Responsible Agency	Permit/Approval	Schedule
City of Rancho Cucamonga	Construction and Grading Permit	To be obtained before construction begins.

7.15.8 References

Anderson, M.L., Roberts, C.W., and Jachens, R.C., 2000. *Principal Facts for Generating Stations in the Vicinity of San Bernardino, Southern California*. U.S. Geological Survey Open-File Report 00-193.

Blake, T.F., 2004. EQFAULT, A Computer Program for the Deterministic Prediction of Peak Horizontal Acceleration from Digitized California Faults.

Campbell, K.W. and Y. Bozorgnia, 1997 revised 2003. "Updated near-source ground motion (attenuation) relations for the horizontal and vertical components of peak ground acceleration and acceleration response spectra." *Bulletin of the Seismological Society of America*, Volume 93, No. 1, February 2003, pp. 314-331.

Cao, Tianqing, Bryant, W.A., Rowshandel, B., Branum, D., and Wills, C.J., 2003. The Revised 2002 California Probabilistic Seismic Hazard Maps, California Geological Survey.

City of Rancho Cucamonga, 2001a. 2001 General Plan.

City of Rancho Cucamonga, 2001b. Geotechnical Hazard Map, 2001 General Plan.

DeMets, C., Gordon, R.G., Stein, S., and Argus, D.F., 1987. "A revised estimate of Pacific-North American motion and implications for western North American plate boundary zone tectonics." *Geophysical Research Letters*. Volume 14, pp. 911-914.

Eckis, R.W., 1928. "Alluvial fans of the Cucamonga district, southern California." *Journal of Geology*, Volume 36, pp. 224-247.

Grove, M., Jacobson, C.E., Barth, A.P., and Vucic, A., 2003. "Temporal and spatial trends of Late Cretaceous-early underplating of Pelona and related schist beneath southern California and southwestern Arizona." in Johnson, S.E., Paterson, S.R., Fletcher, J.M., Girty, G.H., Kimbrouogh, D.L., and Martin-Barajas, A., eds., Tectonic evolution of northwestern Mexico and the southwestern USA: Geological Society of America Special Paper 374, pp. 381-406.

Hart, E.W., revised 1994. *Fault rupture hazard zones in California*. California Division of Mines and Geology Special Publication 42.

Hart, E.W., and Bryant, W.A., 1997. *Fault-Rupture Hazard Zones in California*, Department of Conservation, Division of Mines and Geology Special Publication, 42, 38 p.

Hull, A.G., 1990. Seismotectonics of the Elsinore-Temecula trough, Elsinore Fault zone, southern California. Santa Barbara, California, University of California, Ph.D. dissertation, 233 p.

Hull, A.G., and Nicholson, C., 1992. "Seismotectonics of the northern Elsinore Fault zone, southern California." *Seismological Society of America Bulletin*, Volume 82, pp. 800-818.

Jennings, C.W., 1994. Fault Activity Map of California, California Division of Mines and Geology.

Kennedy, M.P., 1977. *Recency and character of faulting along the Elsinore fault zone in southern Riverside County, California*. California Division of Mines and Geology Special Report 131, 12 p.

Langenkamp, D. and J. Combs, 1974. "Microearthquake study of the Elsinore fault zone, southern California." *Seismological Society of America Bulletin*, Volume 64, No. 1. pp. 187-203.

Matti, J.C., Morton, D.M. and Cox, B.F., 1992. The San Andreas Fault system in the vicinity of the central Transverse Ranges province, southern California: U.S. Geological Survey Open-File Report 92-354.

Meisling, K.E., 1984. Neotectonics of the north frontal fault system of the San Bernardino Mountains, southern California: Cajon Pass to Lucerne Valley: Pasadena, California, California Institute of Technology, Ph.D. dissertation, 394 p.

Meisling, K.E., and Weldon, R.J., 1989. "Late Cenozoic tectonics of the northwestern San Bernardino Mountains, southern California." *Geological Society of America Bulletin*, Volume 101, pp. 106-128.

Miller, F.K., 1987. "Reverse-fault system bounding the north side of the San Bernardino Mountains," in Morton, D.M., and Yerkes, R.F., eds., Recent reverse faulting in the Transverse Ranges, California: U.S. Geological Survey Professional Paper 1339, p. 8395.

Morton, D.M., 1976. Geologic map of the Cucamonga Fault zone between San Antonio Canyon and Cajon Creek, southern California: U.S. Geological Survey Open-File Report 76-726, scale 1:24,000.

Morton, D.M., 1977. "Surface deformation in part of the San Jacinto Valley, southern California." *U.S. Geologic Survey Journal of Research*, Volume 5, n. 1, pp. 117-124.

Morton, D.M. and Matti, J.C., 1987. "The Cucamonga Fault zone: Geologic setting and Quaternary history," in Morton, D.M., and Yerkes, R.F., eds., Recent reverse faulting in the Transverse Ranges, California: U.S. Geological Survey Professional Paper 1339, pp. 179-203.

Morton, D.M. and Matti, J.C., 1989. "A vanished late Pliocene to early Pleistocene alluvial fan complex in the northern Perris Block, southern California," in Colburn, I.P., Abbott, P.L., and Minch, J., eds., Conglomerates in basin analysis: A symposium dedicated to A.O. Woodford: *Pacific Section Society Economic of Paleontologists and Mineralogists*, Volume 62, pp. 73-80.

Morton, D.M. and Matti, J.C., 1993. "Extension and contraction within an evolving divergent strike-slip fault complex: The San Andreas and San Jacinto Fault zones at their convergence in southern California," in Powell, R.E., Weldon, R.J., and Matti, J.C., eds., The San Andreas Fault system: displacement, palinspastic reconstruction, and geologic evolution, *Geological Society of America Memoir* 178, pp. 217-230.

Morton, D.M. and Miller, F.K, 2006. Geologic Map of the San Bernardino and Santa Ana 30' × 60' quadrangles, California, U.S. Geological Survey Open-File Report 2006-1217 Version 1.0.

Seismo-watch.com, 2007. Landers Earthquake Narrative. Available at http://www.seismo-watch.com/EQSERVICES/NotableEQ/Jun/Landers.scec.images/lanhill2.JPG, accessed on January 15, 2007.

Sharp, R.V., 1967. "San Jacinto Fault zone in the Peninsular Ranges of southern California." *Geological Society of America Bulletin*, Volume 78, pp. 705-729.

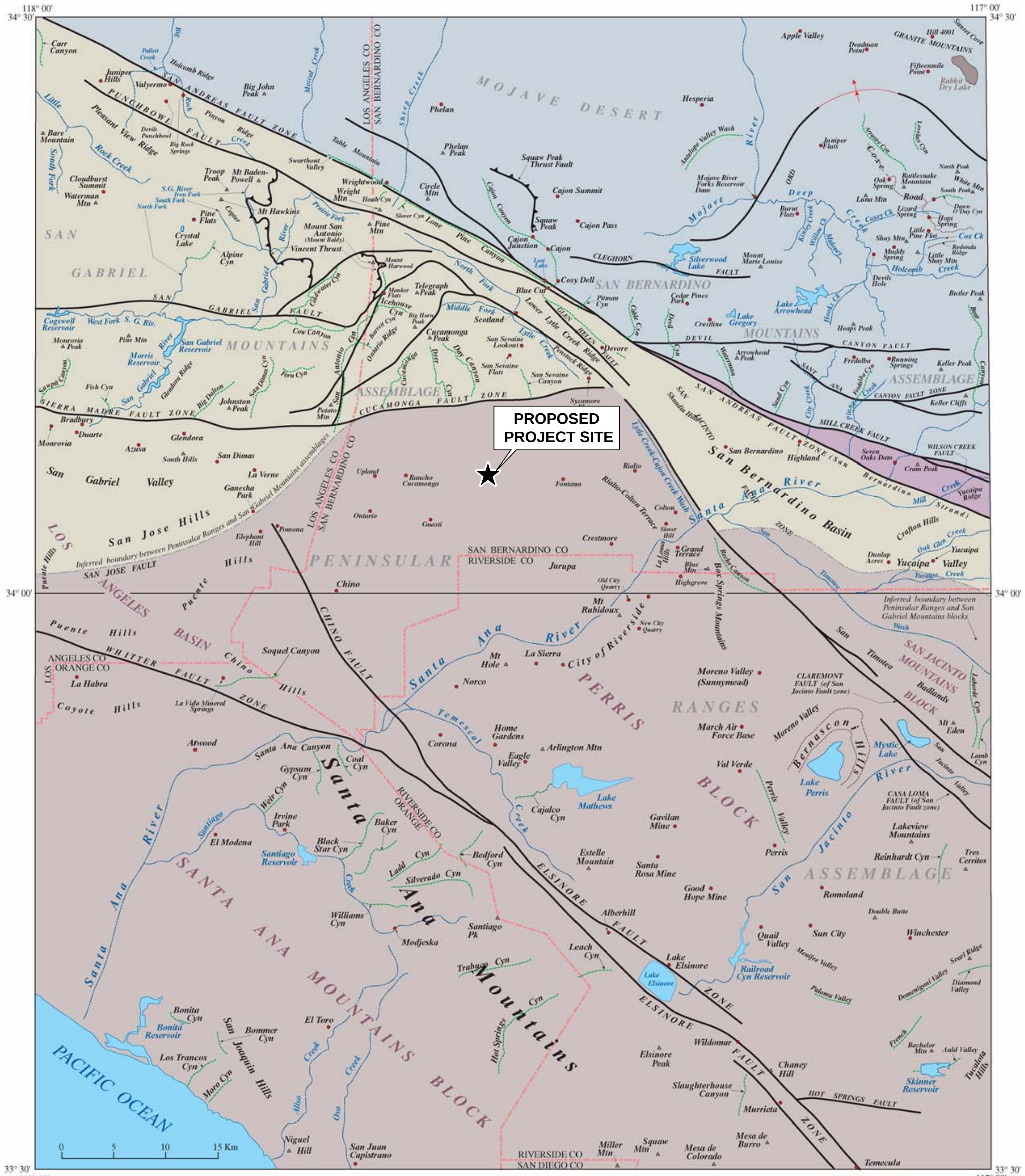
SCEC (Southern California Earthquake Center), 2007. Chronological Earthquake Index. Available at http://data.scec.org/chronoindex/quakedex.html, accessed January 15, 2007.

Weber, F.H. Jr., 1976. Preliminary map of faults of the Elsinore and Chino Fault zones in northeastern Riverside County, California, showing accompanying features related to character and recency of movement. California Division of Mines and Geology Open-file Report 76-1 LA.

Weldon, R.J. and Humphreys, E., 1986. "A kinematic model of southern California." *Tectonics*, Volume 5, pp. 33-48.

Woolfenden. L.R., and Kadhim, D., 1997. *Geohydrology and water chemistry in the Rialto-Colton basin. San Bernardino County, California.* U.S. Geological Survey Water-Resources Investigations Report 97-4012.

Working Group on California Earthquake Probabilities, 1995. "Seismic hazards in Southern California: Probable earthquakes, 1994-2024." *Bulletin of the Seismological Society of America*, Volume 85, pp. 379-439.



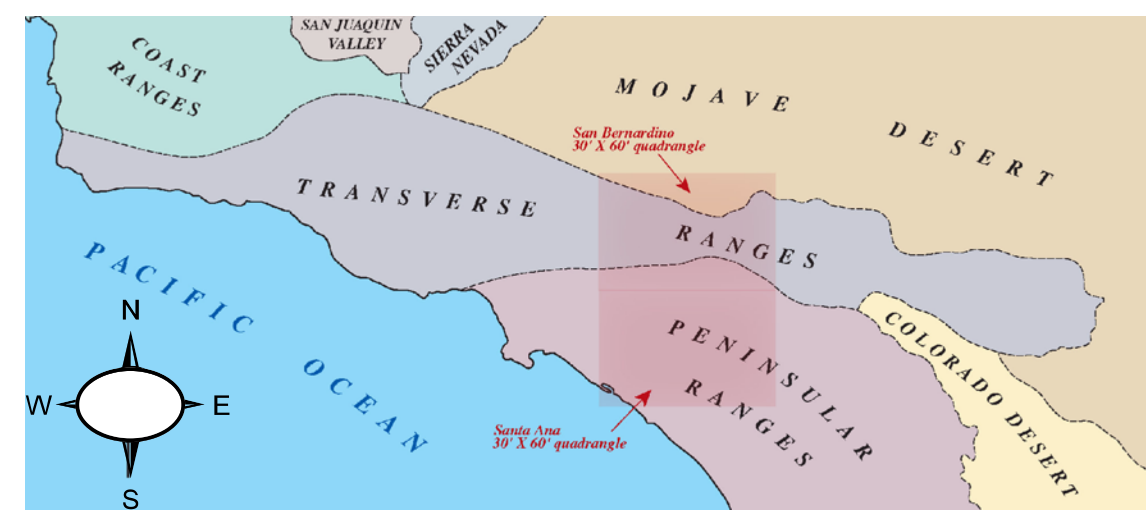
LEGEND

Rocks of the Peninsular Ranges assemblage.

Rocks of the San Gabriel Mountains assemblage. Includes basement (mostly concealed by Quaternary deposits) that is offset by the San Jacinto Fault

Rocks of the San Bernardino Mountains assemblage. Includes basement (mostly concealed by Quaternary deposits) of the Mojave Desert, which is similar to San Bernardino Mountains basement

Rocks bounded by Mission Creek segment of San of the Andreas Fault Zone, and the Mill Creek Fault



Source: USGS, Open-File Report 2006-1217, version 1.0,
"Geologic Map of the San Bernardino and Santa Ana 30' x 60' quadrangles, California"
Authored by Douglas M. Morton and Fred K. Miller.
Digital prepartaion by Pamela M. Cossette and Kelly R. Bovard.
Graphically reorganized from Figures 1 and 2 (of2006-1217_fig1_and2.pdf).

TECTONIC PROVINCES AND CRUSTAL BLOCKS OF SOUTHERN CALIFORNIA

April 2007
28067169

San Gabriel Generating Station
San Gabriel Power Generation, LLC
Rancho Cucamonga, California

URS

FIGURE 7.15-1

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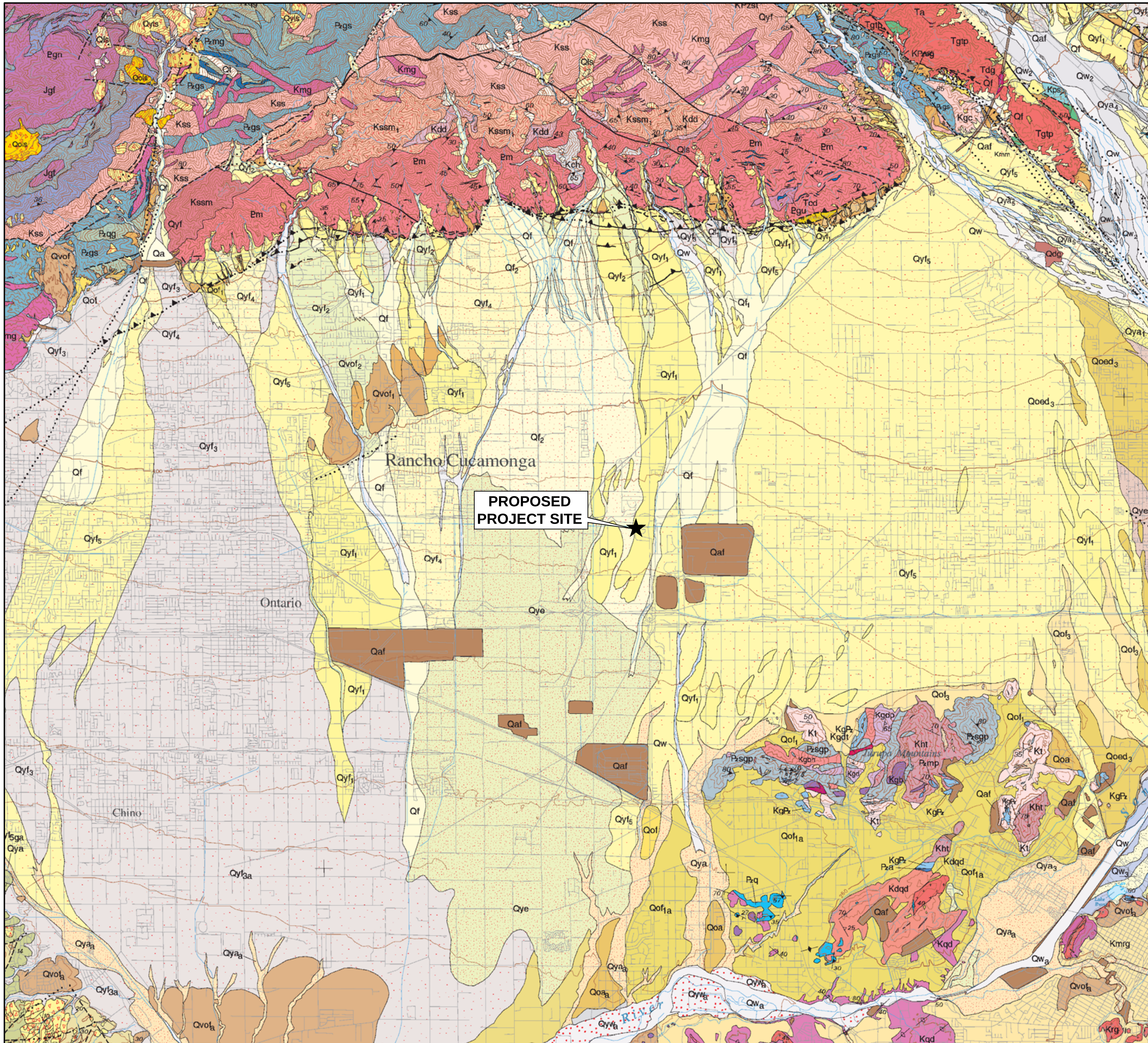

EXPLANATION

Contact—Solid where accuracy of location ranges from well located to approximately located; dashed where very poorly located or inferred.

Fault—Solid where accurately located, dashed where approximately located, dotted where concealed. Includes strike slip, normal, reverse, oblique, and unspecified slip. Arrow and number indicate direction and amount of dip.

Thrust fault—Teeth on upper plate; solid where accurately located, dashed where approximately located, dotted where concealed. Arrow and number indicate direction and amount of dip.

Rotational slip normal fault—Bars on hanging wall side; solid where accurately located, dashed where approximately located, dotted where concealed.

Topographic lineaments— Aligned saddles, swales, and canyons.

Suture—Location approximate

Ground fissures—San Jacinto Valley area

Anticline—Solid where accurately located; dashed where approximately located; dotted where concealed. Arrowhead on axis shows direction of plunge

Syncline—Solid where accurately located; dashed where approximately located; dotted where concealed. Arrowhead on axis shows direction of plunge

Overturned anticline—Solid where accurately located; dashed where approximately located; dotted where concealed. Arrowhead on axis shows direction of plunge

Overturned syncline—Solid where accurately located; dashed where approximately located; dotted where concealed. Arrowhead on axis shows direction of plunge

Monocline—Well located

Strike and dip of bedding

- **Horizontal**
- 70 **Inclined**
- **Vertical**
- 70 **Overturned**

Strike and dip of foliation, primary igneous

- 70 **Inclined**
- **Vertical**

Strike and dip of foliation, metamorphic

- 70 **Inclined**
- **Vertical**

Bearing and plunge of linear features

- 70 **Inclined**

Note:
Map Legend references are located in Table 7.15-1.

N

2.5 1.25 0 2.5 Miles

Source:
USGS, Open-File Report 2006-1217, version 1.0, "Geologic map of the San Bernardino and Santa Ana 30' x 60' quadrangles, California" Authored by Douglas M. Morton and Fred K. Miller. Digital preparation by Pamela M. Cossette and Kelly R. Bovard.

REGIONAL GEOLOGY MAP

San Gabriel Generating Station
San Gabriel Power Generation, LLC
Rancho Cucamonga, California

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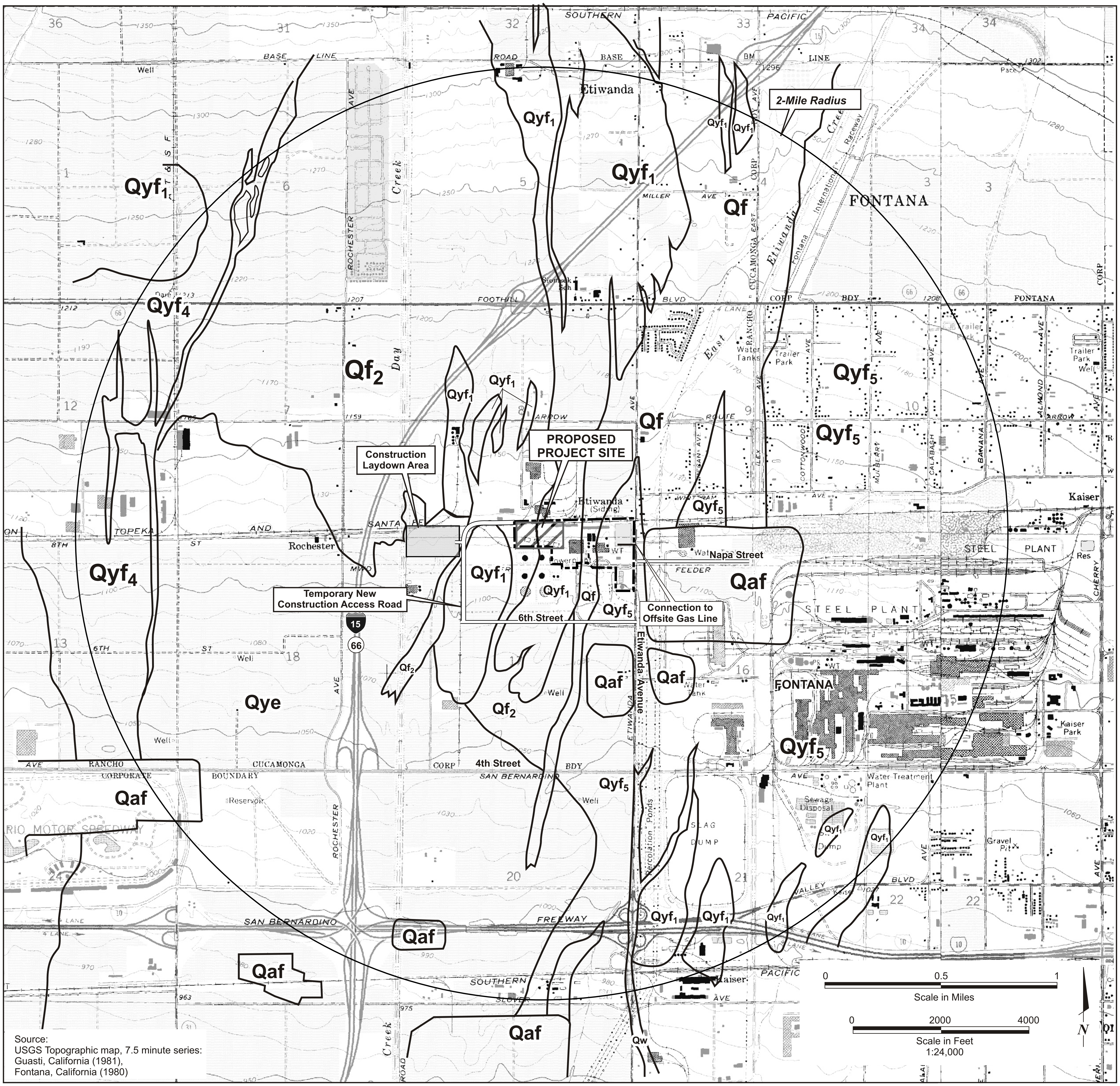
FIGURE 7.15-2

4/09/07 vsa/hk ..T:\Reliant Etiwanda\Graphics\7.15 Geohazards\7.15-2_reg geo.ai



LEGEND

Symbol	Description
(hatched box)	Propseod Project Site
(dash-dot line)	Property Boundary
Qaf	Artificial fill (late Holocene)
Qf	Very young alluvial-fan deposits (late Holocene)
Qf_2	Very young alluvial-fan deposits, Unit 2
Qyf	Young alluvial-fan deposits, Unit 2
Qyf_1	Young alluvial-fan deposits, Unit 1 (early Holocene and late Pleistocene)
Qyf_4	Young alluvial-fan deposits, Unit 4 (late Holocene)
Qyf_5	Young alluvial-fan deposits, Unit 5 (late Holocene)
Qye	Young eolian deposits (Holocene and late Pleistocene)

GEOLOGY OF THE STUDY AREA

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FIGURE 7.15-3

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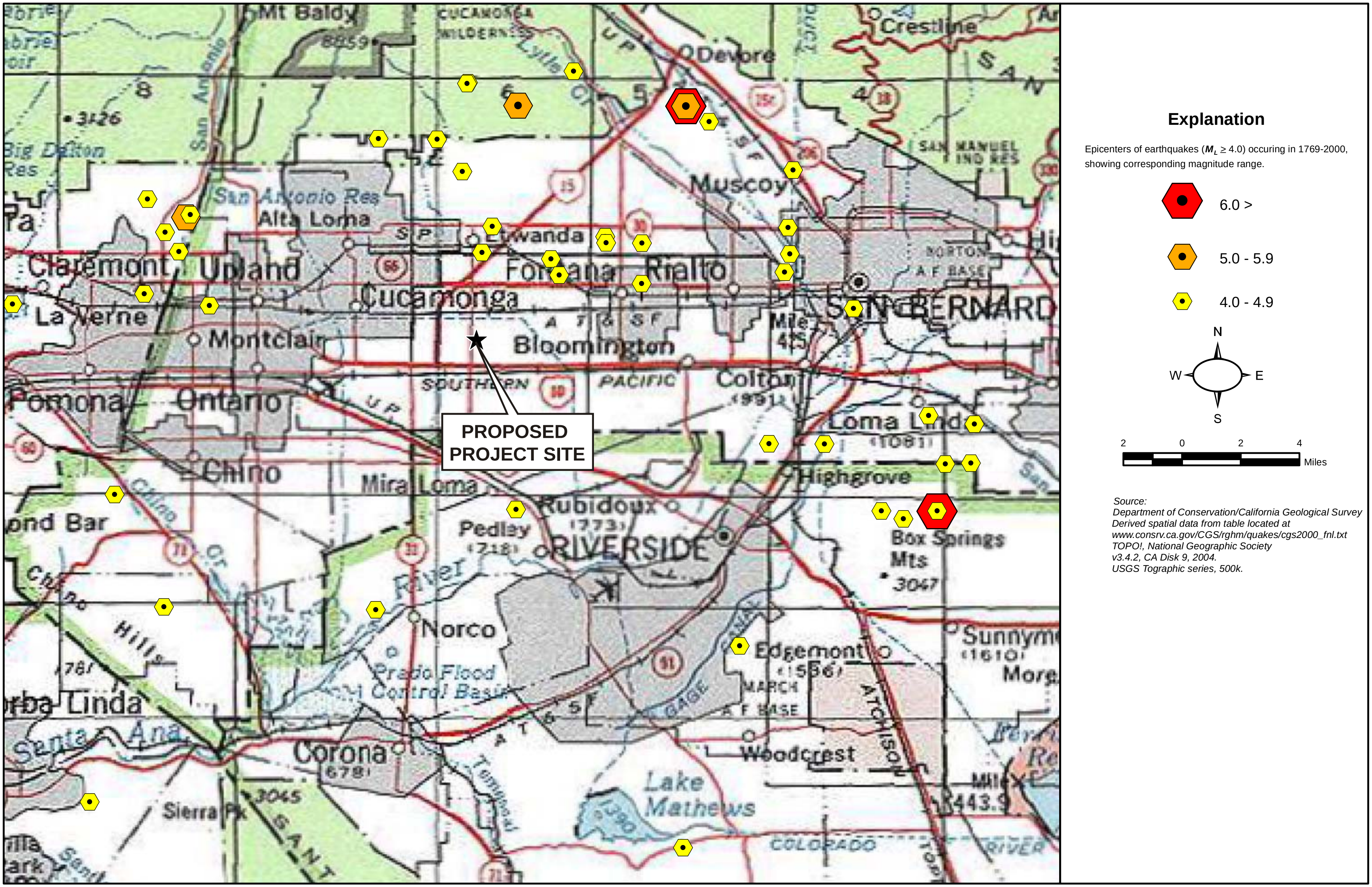

HISTORIC SEISMICITY 1932-2000 IN THE PROPOSED PROJECT VICINITY

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FIGURE 7.15-4

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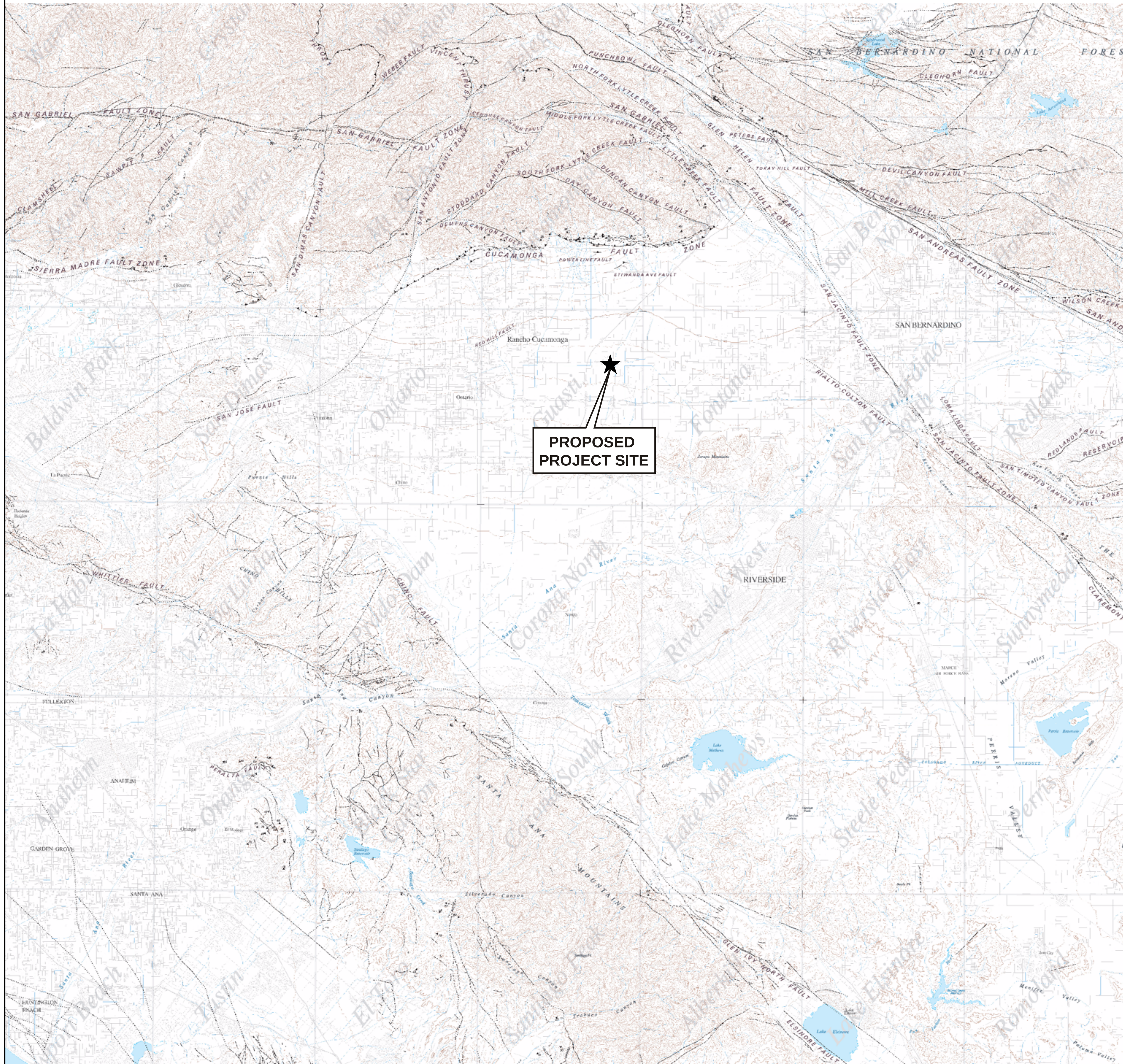

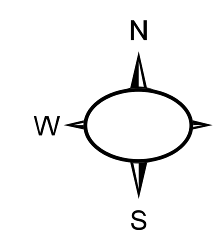

Not to Scale

Source: USGS, Open-File Report 2006-1217,
"Geologic Map of the San Bernardino and Santa Ana 30' x 60' quadrangles, California, version 1.0"
"Major Faults"
Authored by Douglas M. Morton and Fred K. Miller.
Digital prepartaion by Pamela M. Cossette and Kelly R. Bovard.
Zoom extract from of2006-1217_major_flts.pdf.

MAJOR FAULTS
IN THE PROPOSED PROJECT VICINITY

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FIGURE 7.15-5

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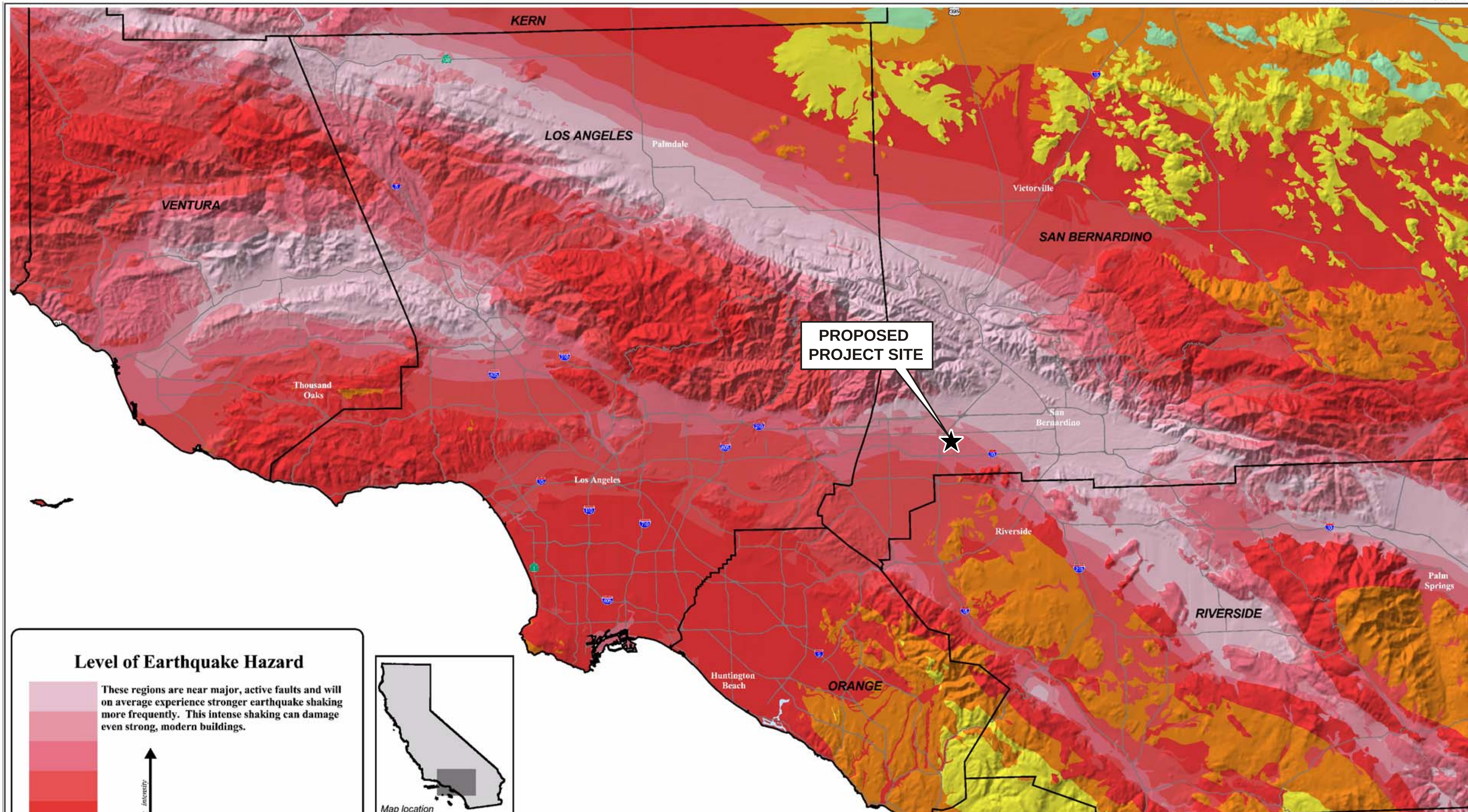
STATE OF CALIFORNIA - GRAY DAVIS, GOVERNOR



Level of Earthquake Hazard

These regions are near major, active faults and will on average experience stronger earthquake shaking more frequently. This intense shaking can damage even strong, modern buildings.

Increasing intensity

These regions are distant from known, active faults and will experience lower levels of shaking less frequently. In most earthquakes, only weaker, masonry buildings would be damaged. However, very infrequent earthquakes could still cause strong shaking here.

County boundaries
Highways
Water

0 5 10 Miles
0 5 10 Kilometers

Map location

Important messages about earthquakes for the Los Angeles metropolitan area:

- Earthquakes have produced over $55 billion in losses in California since 1971. The next large earthquake may produce even greater losses, especially if it affects a major urban area. If the Northridge or Loma Prieta earthquakes had occurred closer to a major population center, fatalities would have been much higher.
- A large earthquake in or near the Los Angeles metropolitan area will disrupt the economy of the entire State and much of the nation. Effective disaster planning by State and local agencies, and by private businesses, can dramatically reduce losses and speed recovery. (For information go to www.oes.ca.gov or www.seismic.ca.gov.)
- Current building codes will reduce damage but their objective is life safety, not continued operation of the facility.
- After a large earthquake, residents and businesses may be isolated from basic police, fire, and emergency support for a period ranging from several hours to a few days. Citizens must be prepared to survive safely on their own, and to aid others, until outside help arrives. (For information go to www.oes.ca.gov.)
- Maps of the shaking intensity after the next major earthquake will be available within minutes on the Internet. The maps available at http://www.cisn.org/shakemap, a cooperative effort of OES, CGS, USGS, Caltech and UC Berkeley, will help identify the areas most seriously affected and will guide emergency crews to the most damaged regions.

Earthquake Shaking Potential for the Los Angeles Metropolitan Region

Counties
Summer, 2003

This map shows the relative intensity of ground shaking and damage in the Los Angeles metropolitan region from anticipated future earthquakes.

www.seismic.ca.gov www.consrv.ca.gov

Data Sources:
California Seismic Safety Commission, California Geological Su
and United States Geological Survey, April, 2003, Earthquake S
Seismic Safety Commission Publication No. 03-02.
Major roads from Thomas Brothers Maps, Inc., 2000, 2001. Sha
DEMs.

EARTHQUAKE SHAKING POTENTIAL FOR THE LOS ANGELES METROPOLITAN REGION

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FIGURE 7.15-6

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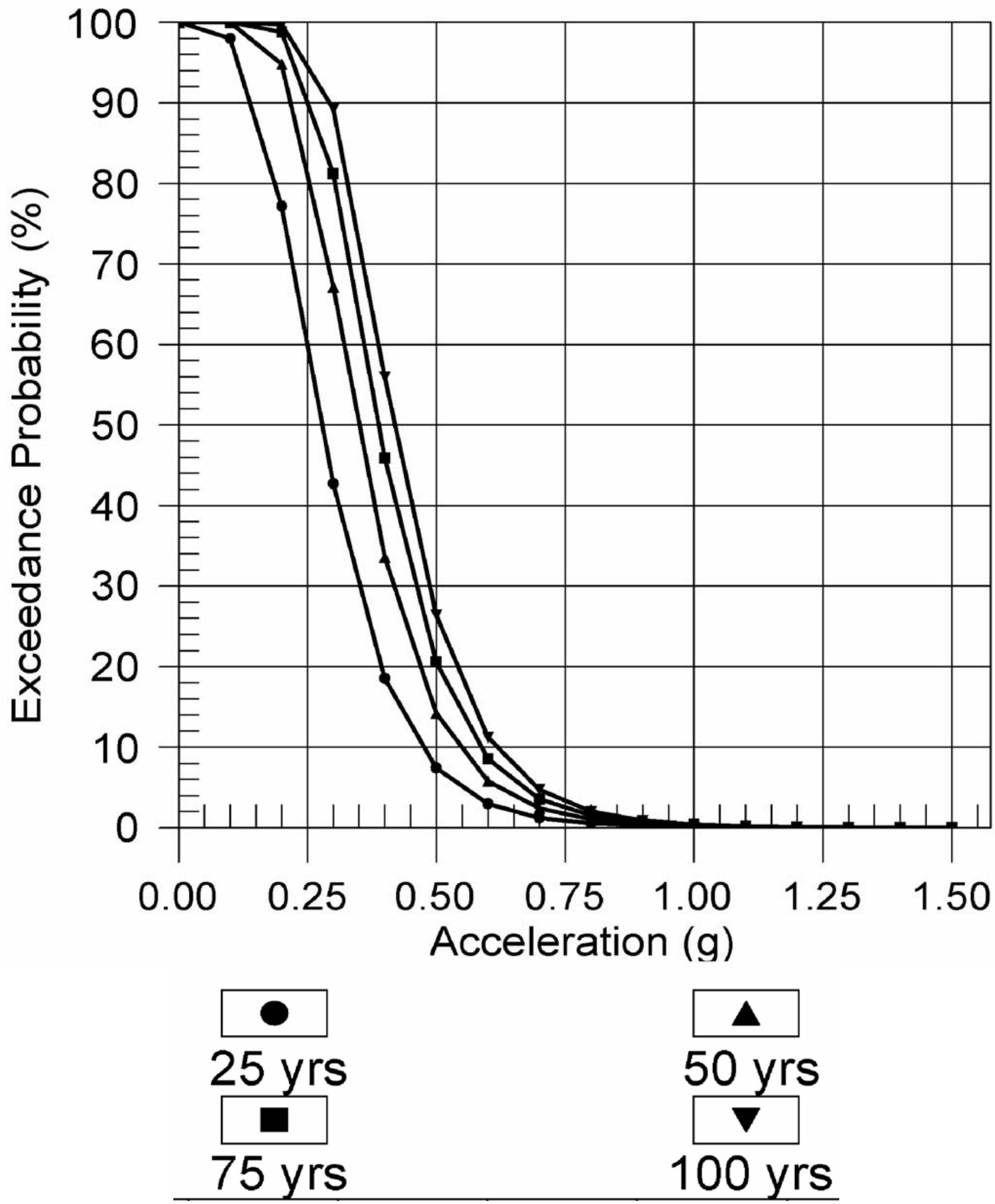

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PROBABILITY OF EXCEEDANCE FOR THE SAN GABRIEL GENERATING STATION

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FIGURE 7.15-7

Reference:
Campbell and Bozorgnia (1997 rev.)

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