Section 3.5
Geology and Soils

3.5.1 Introduction

This section details the geologic conditions at the proposed Project site and analyzes seismicity and faulting; liquefaction, tsunamis and seiches; subsidence; landslides; expansive and corrosive soils; mineral resources; and geologic hazards. This evaluation is based on published and non-published reports, aerial photographs, in-house data, and professional judgment concerning potential geologic hazards.

3.5.2 Environmental Setting

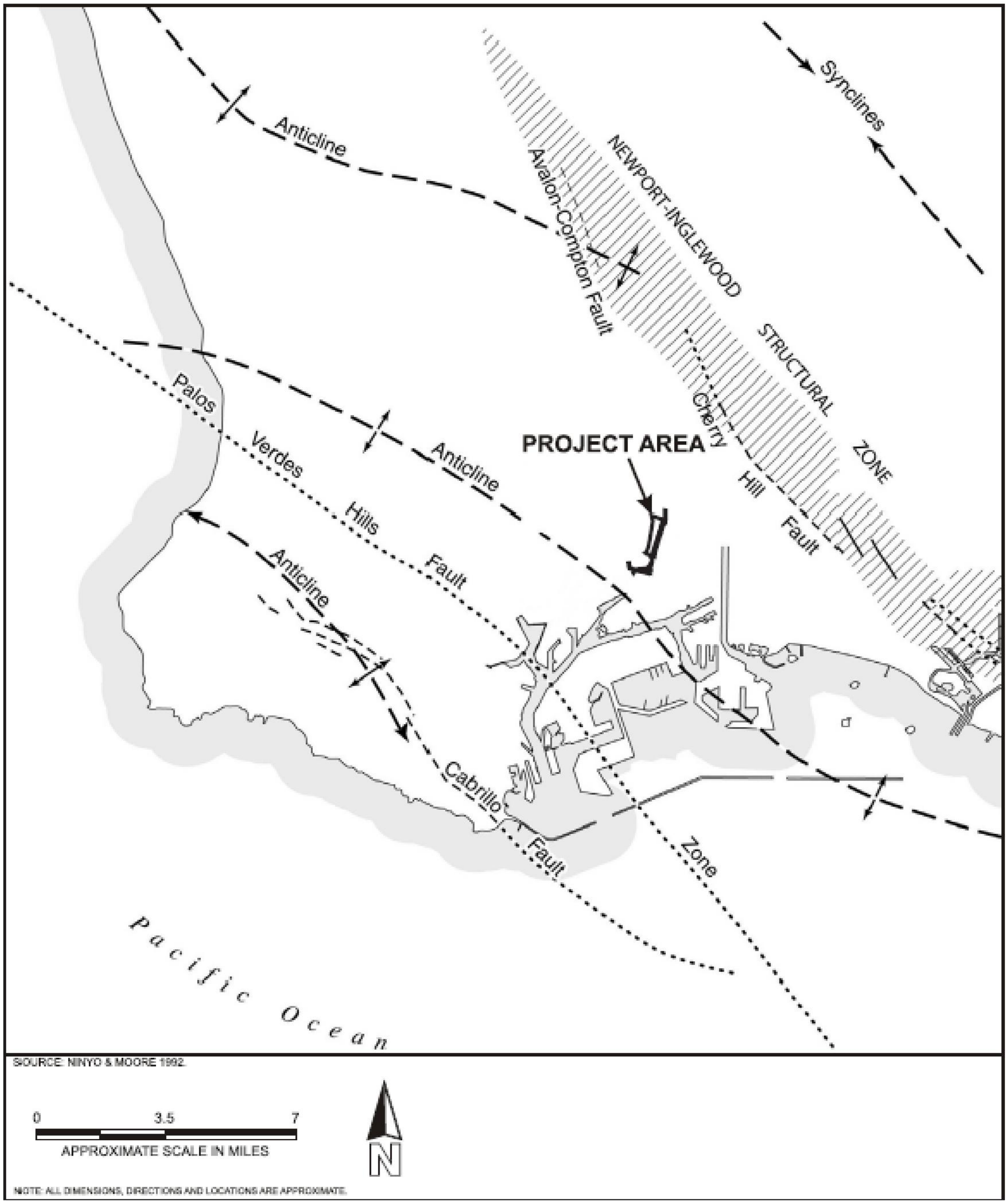
3.5.2.1 Regional Geology

The proposed Project is located in the southwest portion of the Los Angeles Basin in the Peninsular Ranges Geomorphic Province. The Los Angeles Basin has been divided into four structural blocks, which are generally bounded by prominent fault systems: the northwestern, the southwestern, the central, and the northeastern blocks (Norris and Webb, 1990). The southwestern block, which includes the proposed Project, is bounded on the east by the Newport-Inglewood Structural Zone (Figure 3.5-1), which can be traced from Beverly Hills to Newport Bay where it trends offshore. The main structural features of the southwestern block are the anticlinal Palos Verdes Hills that have been raised along a steep reverse fault, several anticlinal ridges in the basement rocks over which younger sediments have been deposited, and intervening broad synclines. The anticlinal structures of the younger rocks have formed important traps for petroleum and natural gas. The basement rocks of the southwestern block, exposed in the Palos Verdes Hills, consist dominantly of green chlorite and blue glaucophane metamorphic rocks of the Catalina Schist. These basement rocks are thought to be late Jurassic to late Cretaceous in age. The overlying younger sediments are Upper Pliocene to Holocene in age (Jennings, 1962; Bryant, 1987; Norris and Webb, 1990). The uppermost Holocene-age deposits are mapped as of alluvium, these consist of clay, silt, and sand (Saucedo, et al, 2003; California Department Water Resources [CDWR], 1961).

3.5.2.2 Local Geology and Soils

The near-surface geology underlying the proposed Project area consists of Holocene-age (young) alluvium (Figure 3.5-2). At the proposed Project site these deposits are approximately 140 feet thick (California Department of Conservation Division of Mines and Geology [CDMG], 1998). According to available reports (The Source Group, not dated.), the soil layers within this area are classified as highly variable, ranging from loose, coarse-grained soils to soft to firm, compressible finer-grained soils. Soil borings performed in the southern portion of the proposed Project site (Ninyo & Moore, 1992) encountered loose, fine-grained sand to 10 feet below ground surface (bgs). Groundwater was also encountered at approximately 8 to 10 feet bgs in these borings.

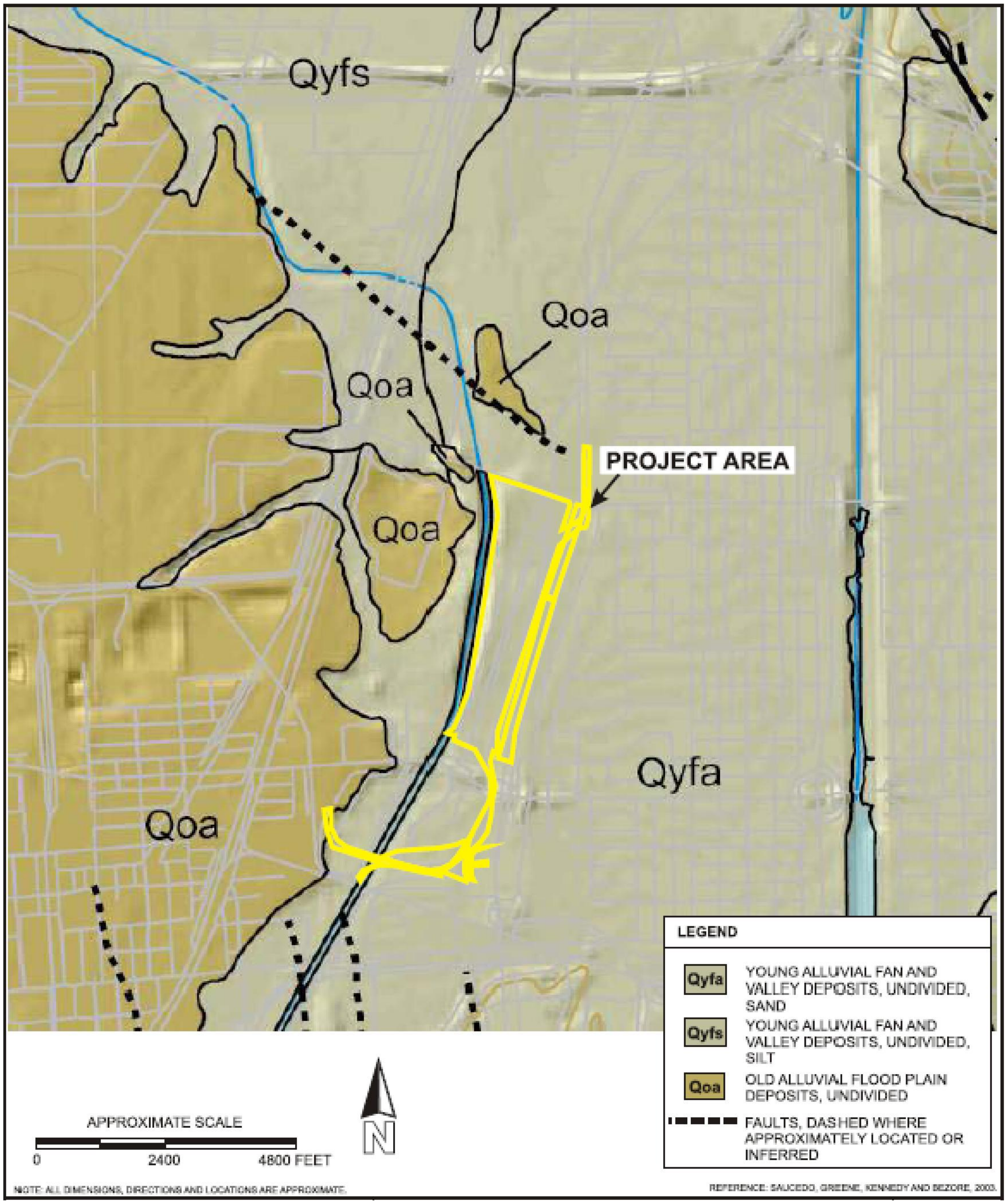
Figure 3.5-1. Site Location Map.



SOURCE: NINYO & MOORE 1992.

NOTE: ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

Figure 3.5-2. Regional Geological Map.



3.5.2.3 Seismicity and Major Faults

An earthquake is classified by the magnitude of wave movement (related to the amount of energy released), which traditionally has been quantified using the Richter scale. This is a logarithmic scale, wherein each whole number increase in Richter magnitude (M) represents a tenfold increase in the wave magnitude generated by an earthquake. A Richter magnitude 8.0 earthquake is not twice as large as a M4.0 earthquake; it is 10,000 times larger (i.e., 10^4, or 10 x 10 x 10 x 10). Damage typically begins at M5.0. Earthquakes of M6.0 to 6.9 are classified as moderate; those between 7.0 and 7.9 are classified as major; and those of 8.0 or greater are classified as great.

Southern California is recognized as one of the most seismically active areas in the United States. The region has been subjected to at least 52 major earthquakes, of magnitude 6 or greater, since 1796. Ground motion in the region is generally the result of sudden movements of large blocks of the earth's crust along faults. Great earthquakes, like the 1857 San Andreas Fault earthquake (see Table 3.5-1), are quite rare in Southern California. Earthquakes of magnitude 7.8 or greater occur at the rate of about two or three per 1,000 years, corresponding to a 6 to 9 percent probability in 30 years. However, the probability of a magnitude 7.0 or greater earthquake in Southern California before 2024 has been estimated at 85 percent (Working Group on California Earthquake Probabilities 1995).

The numerous faults in southern California include active, potentially active, and inactive faults. As defined by the CDMG, active faults are faults that have ruptured during the Holocene (approximately the last 11,000 years). Potentially active faults are those that show evidence of movement during Quaternary time (approximately the last 1.6 million years), but for which evidence of Holocene movement has not been established. Inactive faults have not ruptured in the last approximately 1.6 million years. The approximate locations of major faults in the southern California region and their geographic relationship to the site are shown on Figure 3.5-1. Major active fault zones within approximately 60 miles of the proposed Project include the Palos Verdes, Newport-Inglewood, Whittier-Elsinore, and Malibu-Santa Monica-Raymond Hill Fault Zone (includes the Santa Monica, Hollywood, Malibu Coast and Raymond Hill faults), Cucamonga, and San Andreas (CDMG, 1998; City of Los Angeles, 1977).

Southwest of the proposed Project, the Palos Verdes fault zone trends northwest through Los Angeles Harbor. Northeast of the proposed Project, the Newport-Inglewood fault zone trends northwest. As shown on Figure 3.5-1, fault strands of the Newport-Inglewood fault zone are inferred to trend into the proposed Project area. Based on the proximity of the proposed Project to known active faults, it is reasonable to expect that a strong ground motion seismic event (earthquake) will occur during the lifetime of the proposed Project.

Table 3.5-1 below provides a summary of the major characteristics of the listed major active faults within 60 miles of the proposed Project. Presented are the maximum moment magnitude (Mmax), the nature of movement or type of fault, the slip rate, the designated source type, and the distance in miles (and kilometers) between the proposed Project and the nearest segment of the fault. Specifics of several of these faults are discussed in the following sections of this document.

Table 3.5-1. Major Regional Active Faults within 60 miles of the Project Site.

Fault		Mmax	Fault Type	Slip Rate (mm/yr)	Fault Source Type	Approximate Distance from the Proposed Project in miles (kilometers)
Palos Verdes		7.1	SS	3	B	3.7 (6.0)
Newport-Inglewood (L.A. Basin)		6.9	SS	1	B	2.6 (4.1)
Whittier-Elsinore		6.8	SS	2.5	B	18.0 (28.9)
Newport-Inglewood (Offshore)		6.9	SS	1.5	B	22.8 (36.6)
Malibu-Santa Monica-Raymond Hill Fault Zone	Santa Monica	6.6	DS	1	B	22.4 (36.1)
	Hollywood	6.5	DS	1	B	22.3 (35.9)
	Malibu Coast	6.7	DS	0.3	B	23.9 (38.5)
	Raymond Hill	6.5	DS	0.5	B	22.7 (36.5)
Cucamonga		7.0	DS	0.5	A	36.7 (59.0)
San Andreas-1857 Rupture		7.8	SS	34	A	49.9 (80.3)
San Andreas-Southern		7.4	SS	24	A	49.9 (90.9)

Abbreviations/Notes:

A. Fault Source type is defined by CDMG as follows: Fault exhibits magnitude of 7.0 or greater and slip rate of at least 5 millimeters per year

B. Fault Source type is defined by CDMG as follows: Fault exhibits magnitude of 6.5 to 7.0 range with slip rates varying depending on maximum magnitude

DS.Dip Slip

Mmax = Moment magnitude, a measure replacing the Richter scale that gives the most reliable estimate of earthquake size by the use of the seismic moment in the evaluation of energy release by an earthquake in regards to actual rupture characteristics.

S. Strike Slip

Reference: Blake, T.F., 2001, (FRISK Version 4.00); Cao et al., 2003

3.5.2.3.1 Palo Verdes Fault

The Palos Verdes fault zone trends northwest along the eastern flanks of the Palos Verdes peninsula, approximately 3 miles southwest of the proposed Project site, and extends offshore to the southeast and northwest. Within Los Angeles Harbor, the location of the fault is not well defined, but current data suggest the fault likely passes beneath the West Basin, Terminal Island, and Pier 400 (LAHD, 2004, 2006). The fault zone is approximately 0.6 to 0.9 mile wide, and includes five mapped fault segments. Although dominantly a right-lateral strike slip fault, it does have a component of reverse separation (SCEDC, 2008a). Although no damaging earthquakes are known to have been associated with the Palos Verdes fault, some studies have reported displacement of Holocene-age material and evidence of active fault movement along offshore segments of this fault zone (Treiman and Lundberg, 2005).

The Palos Verdes fault zone has not been designated by the State of California as being within an Earthquake Fault Zone (formerly known as Alquist-Priolo Special Studies Zones). Zoning by the State is contingent on sufficient evidence of fault activity, such as recorded seismic activity and/or geologic evidence to demonstrate fault surface displacement within Holocene time. Due to the presence of urban development and the fact that the fault zone is not well defined, sufficient geologic data have not been developed for zoning by the State. However, the Palos Verdes fault zone is mapped as active by the City of Los Angeles (City of Los Angeles, 1996). Additionally, offshore portions of the Palos Verdes fault zone are mapped as active by Jennings (1994). Therefore, this fault should be considered as a potential source for strong ground motion and possible surface rupture in the proposed Project area.

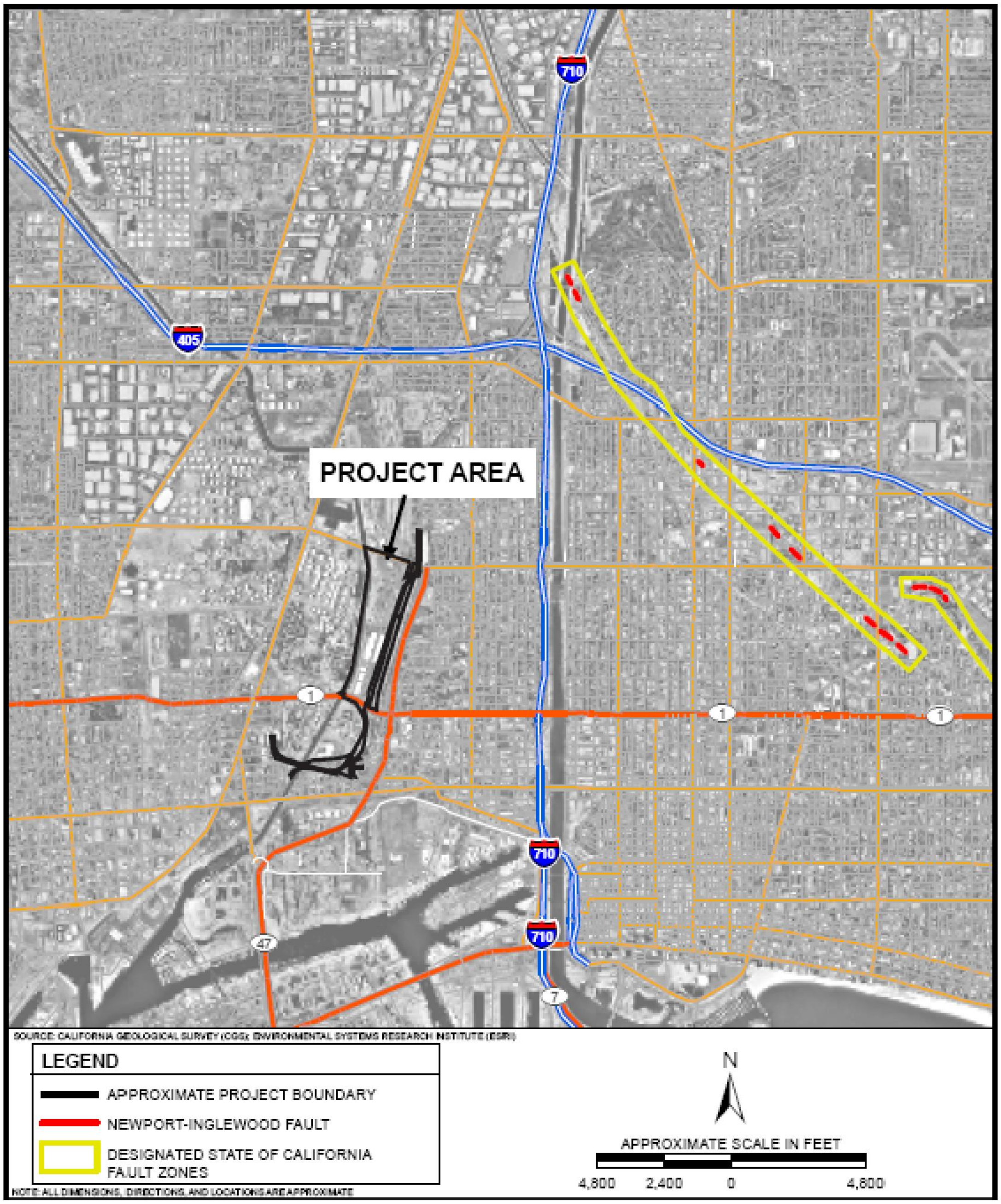
3.5.2.3.2 Newport-Inglewood Fault Zone

The Newport-Inglewood fault zone is located approximately 2.6 miles northeast of the proposed Project, and as shown on Figure 3.5-3 there are strands projecting into the proposed Project area. The Newport-Inglewood fault zone is a major tectonic structure in the Los Angeles Basin and consists of a series of disconnected, northwest-trending fault segments that extend from the southern edge of the Santa Monica Mountains, through Long Beach and Torrance, southeast to the area offshore of Newport Bay. This fault zone is reflected at the surface by a line of geomorphically young anticlinal hills and mesas formed by the folding and faulting of a thick sequence of Pleistocene-age sediments and Tertiary-age sedimentary rocks. The zone of faulting and deformation is estimated to be approximately 1 to 2½ miles wide at the surface. Although displacements on the Newport-Inglewood fault zone have both vertical and horizontal components, movement is dominantly right-lateral, strike-slip (SCEDC, 2008a).

Segments of the Newport-Inglewood fault have been designated as within Earthquake Fault Zones by the state of California. This designation was given to this “sufficiently active” fault after extensive geologic and seismic studies. The designation of an earthquake fault zone was established to help mitigate the hazards of fault rupture by prohibiting structures built for human occupancy across the trace of known active earthquake faults.

The Newport-Inglewood fault poses a seismic hazard to Los Angeles County. The Newport-Inglewood fault zone was the source of the 1933 Long Beach earthquake. The hypocenter of the 1933 earthquake was located just off the coast of Newport Beach at a depth of about 10 kilometers with a measured magnitude of Mw 6.3. Ground cracking resulting from soil liquefaction, lateral spreading, and ground lurching was observed after the 1933 Long Beach earthquake. Although no onshore surface fault rupture has taken place in historic times, the fault zone is considered capable of strong ground motion in the proposed Project area.

Figure 3.5-3. Fault Zone Location Map.



SOURCE: CALIFORNIA GEOLOGICAL SURVEY (CGS); ENVIRONMENTAL SYSTEMS RESEARCH INSTITUTE (ESRI)

NOTE: ALL DIMENSIONS, DIRECTIONS, AND LOCATIONS ARE APPROXIMATE

3.5.2.3.3 Whittier-Elsinore Fault Zone

The Whittier-Elsinore fault zone is one of the more prominent structural features in the Los Angeles Basin. The Whittier fault zone, located approximately 18 miles north of the proposed Project, extends approximately 24 miles from Whittier Narrows in Los Angeles County southeast to Santa Ana Canyon in Orange County, where it merges with the Elsinore fault zone. The Whittier fault zone averages approximately 1,000 to 2,000 feet in width and is made up of many sub-parallel and en echelon fault splays, which merge and branch along their course. Current information indicates that the Whittier fault zone is active and may be capable of generating an earthquake of magnitude 6.8 accompanied by surface rupture along one or more of its fault traces.

The Elsinore fault zone extends approximately 112 miles (180 kilometers) from its southeastern extension, the Laguna Salada fault, to where it splays into two segments, the Chino fault and Whittier fault, at its northern end near Santa Ana Canyon. The main trace of the Elsinore fault zone has experienced one historical event greater than magnitude 5.2, known as the Earthquake of 1910, which was a magnitude 6 earthquake near Temescal Valley that produced no known surface rupture and did little damage. The Elsinore fault zone is active and may be capable of generating an earthquake of magnitude 6.8 accompanied by surface rupture along one or more of its fault traces. Segments of the Whittier-Elsinore fault have been designated as within Earthquake Fault Zones by the state of California. Although the impact on the proposed Project from earthquakes along the Whittier-Elsinore fault zone is considered low relative to other faults discussed in this section, this fault is capable of generating moderate ground motion in the proposed Project area.

3.5.2.3.4 Malibu-Santa Monica-Raymond Hill Fault Zone

The Malibu-Santa Monica-Raymond Hill fault zone, also known as the Frontal Fault System, is located approximately 23 miles north of the proposed Project, and includes the Malibu Coast, Santa Monica, Hollywood and Raymond Hill fault zones. This fault system extends from the base of the San Gabriel Mountains westward to beyond the Malibu coastline. Faults within this system have been active during Quaternary time and probably during the Holocene. Holocene displacement has been documented for the Raymond fault, and has also been inferred for the Hollywood fault. This fault system is considered active (Jennings, 1994) and capable of generating damaging earthquakes. Additionally, segments of the Raymond fault have been designated as Earthquake Fault Zones. Major earthquakes along this system could generate moderate to strong ground motion in the proposed Project area.

3.5.2.3.5 Cucamonga Fault Zone

The Cucamonga Fault Zone is located along the southern margin of the eastern San Gabriel Mounts approximately 48 miles long. The fault zone is located approximately 38 miles northeast of the proposed Project. Movement on the Cucamonga fault zone has been predominantly thrust faulting and it has been active throughout the Quaternary and during the very recent Holocene. Major earthquakes along this system could generate moderate to strong ground motion in the proposed Project area.

3.5.2.3.6 San Andreas Fault Zone

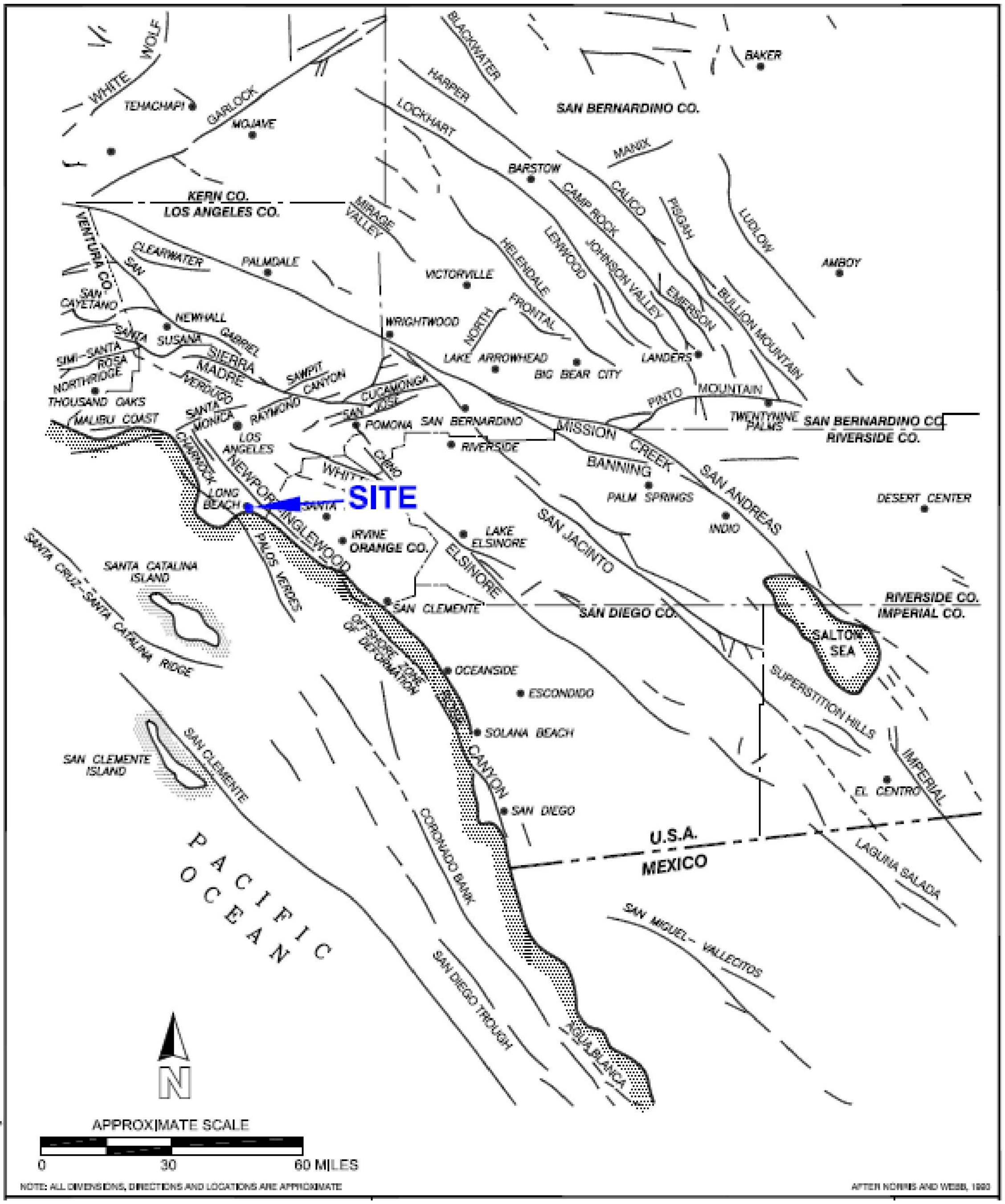
The San Andreas Fault is located approximately 53 miles northeast of the proposed Project (Figure 3.5-4). It has long been recognized as the dominant seismo-tectonic feature in California, and major earthquakes could generate moderate to strong ground motion. Two of California's three largest historic earthquakes, the 1906 San Francisco earthquake and the 1857 Fort Tejon earthquake, occurred along the San Andreas fault. The fault is a right-lateral strike-slip fault which is capable of producing earthquakes approaching Mmax 7.8 (Table 3.5-1). It is inferred that the segment of the San Andreas Fault zone closest to the proposed Project is currently locked and accumulating substantial amounts of strain in response to stresses generated by the relative movement between the Pacific and North American plates. The available geologic and seismic data indicate that this strain is released during infrequent major to great earthquakes (Mw 7 to 8+ events) rather than by more frequent smaller magnitude earthquakes. Major earthquakes along this system could generate moderate to strong ground motion in the proposed Project area.

3.5.2.4 Liquefaction

Liquefaction is a phenomenon in which soil loses its shear strength for short periods of time during an earthquake. Ground shaking of sufficient duration results in the loss of grain-to-grain contact, due to a rapid increase in pore water pressure, causing the soil to behave as a fluid for short periods of time. The effects of liquefaction may include excessive total and/or differential settlement for structures founded in the liquefying soils. To be susceptible to liquefaction, a soil is typically cohesionless, with a grain-size distribution of a specified range (generally sand and silt), loose to medium dense, below the groundwater table, and subjected to a sufficient magnitude and duration of ground shaking.

According to Seismic Hazards Zone Maps published by the state of California (CDMG, 1998) and the City of Long Beach (2006), the proposed Project is within an area considered susceptible to liquefaction (Figure 3.5-5). Liquefaction is considered possible at the proposed Project due to the regional seismic activity and the nature of the on-site soil and groundwater conditions. As noted, there is a relatively high probability that the proposed Project area will experience a significant earthquake during the next 50 years. Extended duration of ground shaking could result in liquefaction and settlement of saturated subsurface materials. The potential damaging effects of liquefaction include differential settlement, loss of ground support for foundations, ground cracking, and heaving and cracking of structure slabs (Tinsley and Youd, 1985). In addition, railroad tracks and roadbed may experience subgrade failure due to liquefaction. During shaking, the stability of ties and ballast may be weakened and rail in compression can force the track to buckle. Shaking may also result in a loss of elevation in curves (AREMA, 2002).

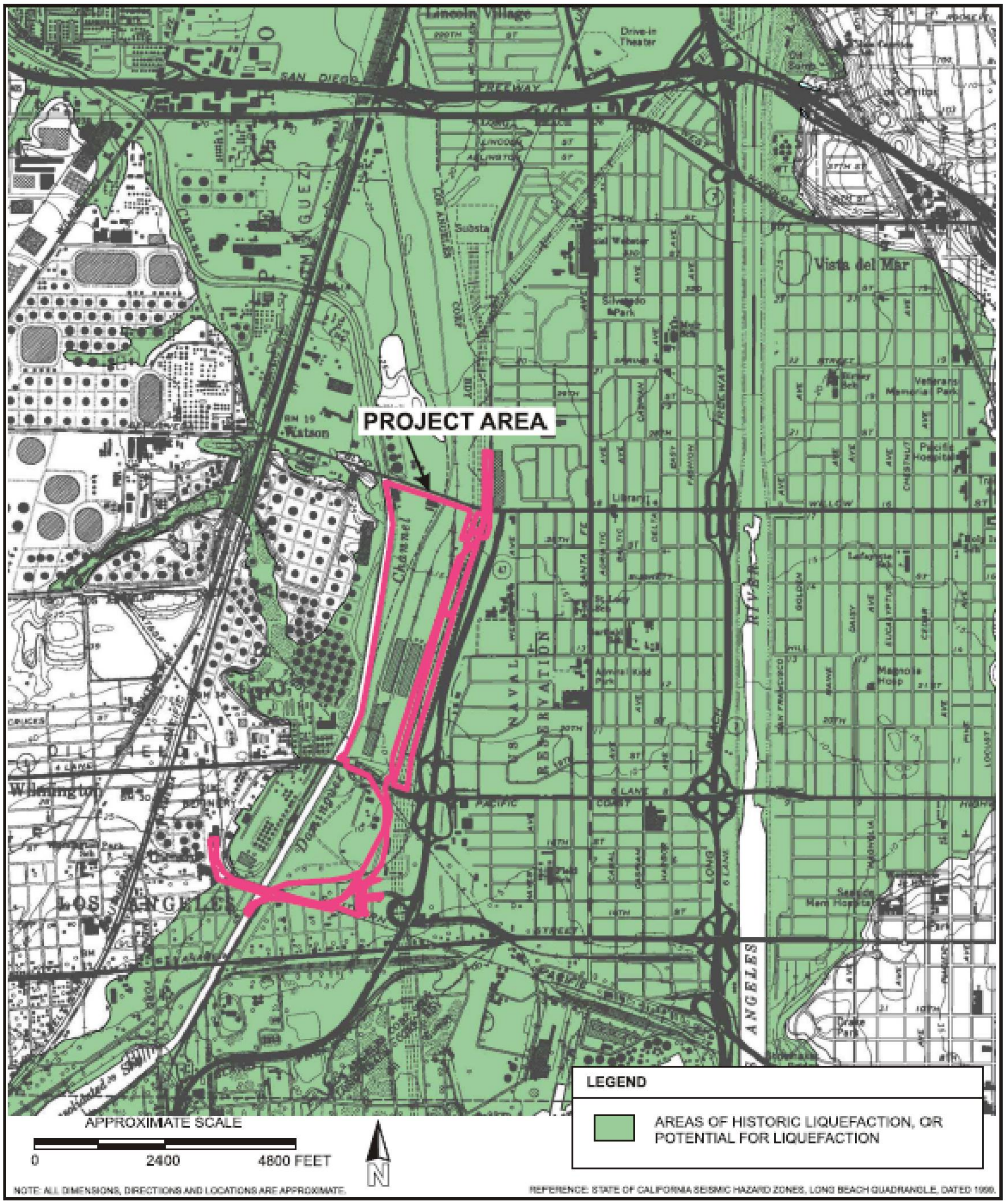
Figure 3.5-4. Fault Location Map.



NOTE: ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE

AFTER NORRIS AND WEBB, 1990

Figure 3.5-5. Seismic Hazard Map.



NOTE: ALL DIMENSIONS, DIRECTIONS AND LOCATIONS ARE APPROXIMATE.

REFERENCE: STATE OF CALIFORNIA SEISMIC HAZARD ZONES, LONG BEACH QUADRANGLE, DATED 1999.

3.5.2.5 Tsunamis and Seiches

Tsunamis are open sea waves generated by undersea landslides, volcanic eruptions, or earthquakes that cause sudden vertical motions of the earth's crust. The vertical displacement of the crust or soil masses causes displacement of the overlying water mass resulting in long period (5 to 60 minutes) oceanic waves with wavelengths up to 125 miles that can travel hundreds of miles across the ocean. As they approach the coast, the waves amplify as their length becomes shorter. The trough of the tsunami wave arrives first, leading to the classic retreat of water from the shore as the ocean level drops. This is followed by the arrival of the crest of the wave, which can run up the shore in the form of bores and surges in shallow water or be expressed as simple rising and lowering of the water level in relatively deeper water such as in harbor areas. In the process of bore/surge-type run-up, the onshore flow (up to tens of feet per second) can cause tremendous dynamic loads on the structures onshore in the form of impact forces and drag forces, in addition to hydrostatic loading. The subsequent drawdown of the water after run-up exerts the often crippling opposite drags on the structures and washes loose/broken properties and debris to sea; the floating debris brought back on the next onshore flow have been found to be a significant cause of extensive damage after successive run-up and drawdown. As has been shown historically, the potential loss of human life in the process can be great if such events occur in populated areas.

A seiche is the seismically-induced sloshing of water in a large enclosed basin, such as a lake, reservoir, bay, or channel, and may be expected in the harbor as a result of earthquakes. Any significant wave front could cause damage to seawalls and docks, and could breach sea walls in the Port. Modern shoreline protection techniques are designed to resist seiche damage. The Los Angeles/Long Beach Port Complex model (Moffatt and Nichol, 2007) found that impacts from a modeled tsunami were equal to or more severe than those from a modeled seiche. Accordingly, the impact discussion below refers primarily to tsunamis as the worst case of potential impacts.

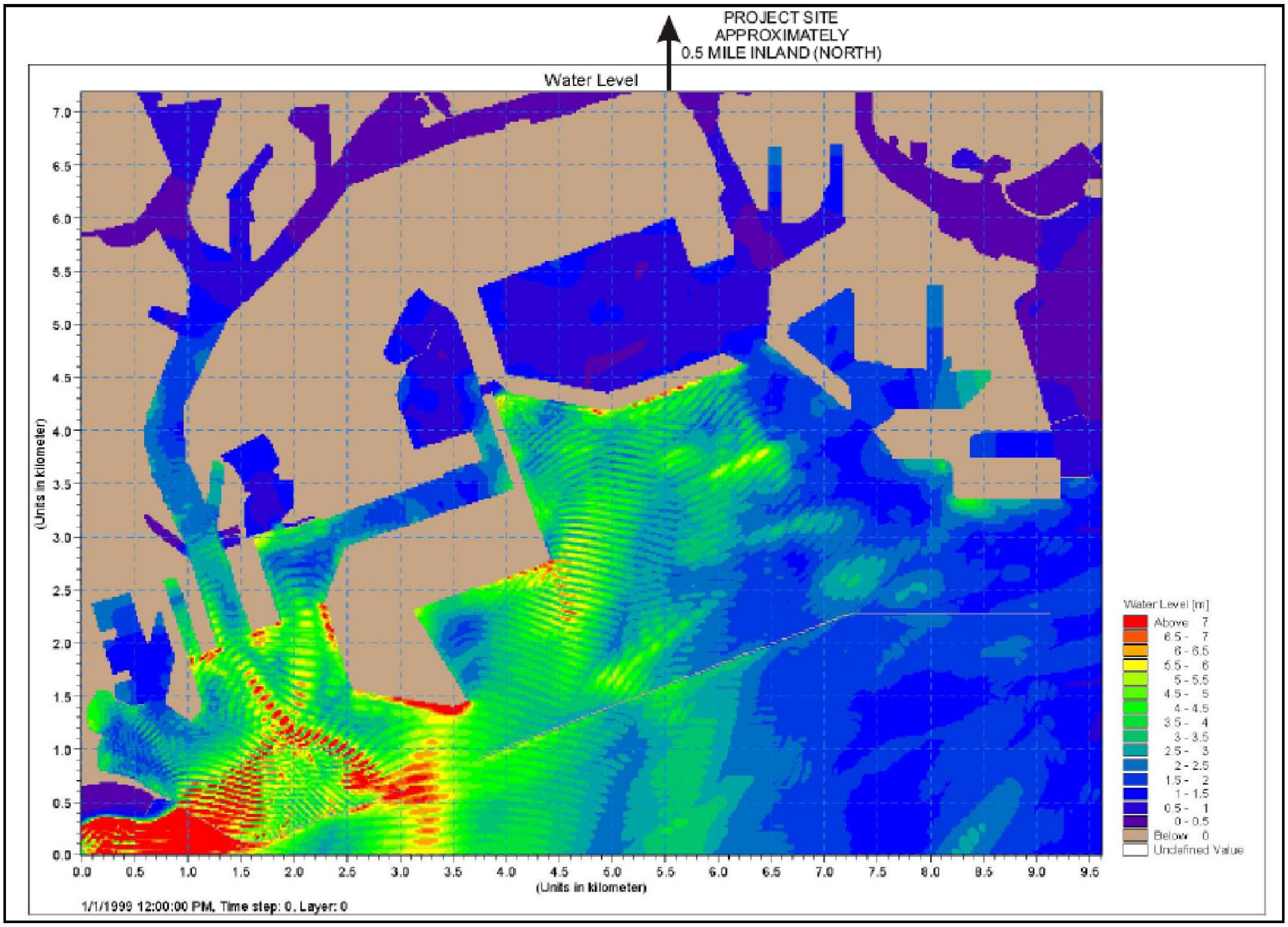
Tsunamis and seiches have caused historic damage along the southern California coastline. The 1960 Chilean earthquake caused tsunami waves at the Los Angeles-Long Beach Harbor resulting in damage to boats and harbor facilities and the death of one person. Seiches caused by the tsunami waves caused approximately 5-foot waves to surge back and forth in the Cerritos Channel. The 1964 Alaska earthquake produced tsunami waves approximately 4 feet in height in San Pedro Bay, Los Angeles Harbor, and Long Beach Harbor, causing damage to several small boat docks, pilings, and the Union Oil Company fuel dock. The damage was largely the result of swift currents and wave oscillation (seiching) in the inner harbor (Randell et al., 1983)

In a recent study by Moffatt & Nichol (2007), potential distant tsunamigenic sources (e.g., faults and submarine landslides) that may affect the area have been identified. Each of the fault sources identified is greater than 60 miles from the proposed Project and include: the Santa Catalina fault (located offshore, to the southwest); three segments of the Lasuen Knoll fault (offshore, to the south); the San Mateo thrust (offshore, to the south); and the Cascadia fault (Cascadia Subduction Zone, located offshore of British Columbia, south to Oregon State).

Generalized modeling by Legg et al. (2004) estimated the frequency of tsunamigenic earthquake events by assuming a 1 mm/yr slip rate and dividing the displacements typical of M ~ 7.0 to 7.6 earthquakes. This is a commonly used procedure for estimating earthquake magnitudes and recurrences when working in areas such as offshore California where there are little specific data on faults or earthquakes. Based on these methods Legg et al. (2004) estimated that tsunamis could be generated every few hundred to few thousand years. In addition, submarine landslides occurring at the Palos Verdes Escarpment (to the west) have been designated as tsunamigenic sources. Modeling by Moffat & Nichol (2007) determined that the event created by a large landslide at the Palos Verdes Escarpment would create the largest tsunami near the area, with a maximum modeled wave height of approximately 21 feet above mean sea level at the mouth of the Port (a distance of more than one mile closer to the coast than the Project area). According to Moffat & Nichol (2007), tsunamigenic landslides are infrequent and probably occur less often than large earthquakes; a recurrence interval of about 10,000 years was suggested as a reasonable estimate.

The potential for tsunamis to affect the proposed Project area can be inferred from the modeling studies of the Port area. Borrero et al. (2005) indicate that a large submarine landslide off the southern tip of the Palos Verdes Peninsula could result in a maximum of 13 feet of runup in the Port of Los Angeles and Port of Long Beach. Tsunami run-up projections developed for the port area in recent studies (e.g., Synolakis et al., 1997) by the California State Lands Commission (CSLC) are approximately 8 feet and 15 feet above mean sea level, at the 100- and 500-year intervals, respectively. Using the more conservative projections from Moffatt and Nichol, modeled water levels approximately one-half mile south of the Project site would be less than 3 feet above mean sea level (none of the modeling efforts extend inland as far as the Project area; the northernmost extent of the Moffatt & Nichol model is approximately one-half mile closer to the coast than the Project area). Furthermore, the Moffatt and Nichol model shows the maximum wave height attenuating rapidly with distance from the coast, going from 21 feet to less than 3 feet within approximately one mile (Figure 3.5-6). Accordingly, the potential for a tsunami to cause substantial flooding or damage at the Project site is remote.

Figure 3.5-6. Maximum Water Levels for the Palos Verdes Landslide II Scenario.



3.5.2.6 Subsidence

Subsidence is the phenomenon where soils and other earth materials underlying a site settle or compress, resulting in a lower ground surface elevation. Regional subsidence has been documented in the vicinity of the proposed Project area due to the removal of subsurface oil and gas reserves in the Wilmington Oil Field. The subsidence was subsequently remedied through a water injection program initiated by the City of Long Beach in 1958 (LAHD, 2004), and subsidence control continues to be maintained through water injection at rates greater than the total volume of produced substances, including oil, gas, and water, to prevent further reservoir compaction and subsidence (City of Long Beach, 2006).

Subsurface exploration at the southern portion of the proposed Project indicated that the soil consists of loose, fine-grained sand (Ninyo & Moore, 1992) that pose the risk of adverse settlement under static loads imposed by addition of fill or structures.

3.5.2.7 Landslides

Landslides, slope failures, and mudflows of earth materials dominantly occur where slopes are too steep and/or the earth materials too weak to support themselves. Most landslides are single events, but more than a third are associated with heavy rains. Landslides may also occur by seismic ground shaking, particularly where high groundwater is present. As shown on the reviewed aerial photographs and maps, there are no significant slopes in the vicinity of the proposed Project, nor are there any significant slopes proposed for project implementation (USDA, 2009). In addition, according to Seismic Hazards Zone Maps published by the state of California (CDMG, 1998) the proposed Project does not lie within an area susceptible to earthquake-induced landslides.

3.5.2.8 Unique Geological/Topographical Features

The proposed Project site has been disturbed by grading to level the site, channelize watercourses, install roads, parking areas, and rail lines, and by operating heavy industrial land uses. No natural or distinct geologic features remain within the site.

3.5.2.9 Soil Conditions

Prior to development of the Los Angeles Harbor, extensive estuarine deposits were present at the mouth of Bixby Slough, Dominguez Channel, and the Los Angeles River, in the general vicinity of the Project site. The estuarine deposits were mostly covered with artificial fill. Dredge fill and natural alluvial soils represent a mix of soil types, predominantly unconsolidated layers of soft-to-hard clays and silts, with sandy soils present in some areas to depths of 40 feet (Saucedo, et al, 2003; California Department Water Resources, CDWR, 1961). According to available reports (The Source Group, n.d., Diaz Yourman & Associates, 2008), the soils at the proposed Project area are classified as highly variable, ranging from loose and coarse-grained to soft-to-firm, compressible finer-grained soils. Soil borings performed in the southern portion of the proposed Project site encountered loose, fine-grained sand to 10 feet bgs, (Ninyo & Moore, 2001). The SCIG Geotechnical Investigation (Diaz Yourman and Associates, 2008) identifies potentially liquefiable soils in the upper 50 feet, soft, compressible, and weak silts and clays, and moisture content of the upper 5 feet of soils at 20 percent above the optimum moisture in some locations.

Expansive soils generally result from specific clay minerals that have the capacity to shrink or swell in response to changes in moisture content. Shrinking or swelling of foundation soils can lead to damage to foundations and engineered structures, including tilting and cracking. Review of regional geologic maps and site-specific subsurface exploration at the proposed Project site (The Source Group, n.d., Diaz Yourman & Associates, 2008) indicate that the near surface soils consist predominately of silty and clayey sands. The granular nature of this material means that soils in the upper five feet have a relatively low potential for expansion.

Unconsolidated fine-grained soils such as those that occur on the proposed Project site are potentially susceptible to wind and water erosion. The fact that very little of the site consists of bare soil means that wind is likely an insubstantial mode of erosion. The flat topography of the Project site would limit erosion by surface water. Nevertheless, erosion of exposed soils can occur during storm events; this issue is addressed in Section 3.12, Water Resources.

3.5.3 Applicable Regulations

Regulatory guidelines regarding geologic hazards and mineral resources within the proposed Project area are promulgated in part by the City of Los Angeles, City of Long Beach, City of Carson, County of Los Angeles, and the State of California. These regulations are summarized below.

3.5.3.1 Regulations Pertaining to Geologic Hazards

3.5.3.1.1 State Regulations

California Building Standards Code. This code is promulgated under California Code of Regulations (CCR), Title 24, Parts 1 through 12 and is administered by the California Building Standards Commission (CBSC). The CBSC is responsible for administering California's building codes.

Alquist-Priolo Fault Zoning Act. This act was enacted in 1972 by the State of California (Pub. Res. Code Sections 2621 et seq.) to mitigate the damage caused by fault rupture during an earthquake. Under this act, faults throughout the state have been evaluated for surface rupture potential during an earthquake event, and Earthquake Fault Zones have been established around active faults (Hart and Bryant, 1997).

Seismic Hazards Mapping Act of 1990. Public Resources Code Sections 2690–2699.6 direct the State Department of Conservation to identify and map areas subject to earthquake hazards, such as liquefaction, earthquake-induced landslides, and amplified ground shaking. In 1990, the State legislature passed the Seismic Hazards Mapping Act which is aimed at reducing the threat to public safety and minimizing potential loss of life and property in the event of a damaging earthquake event. A product of the resultant Seismic Hazards Mapping Program, Seismic Zone Hazard Maps have been developed which identify Zones of Required Investigation; most developments designed for human occupancy within these zones must conduct site-specific geotechnical investigations to identify the hazard and develop appropriate mitigation measures prior to permitting by local jurisdictions.

3.5.3.1.2 Municipal Regulations

City of Los Angeles General Plan. The General Plan contains conservation and safety elements for the protection of geologic features and avoidance of geologic hazards. The procedures for construction-related earthwork and excavation are established by local grading ordinances.

City of Los Angeles Municipal Code. The Municipal Code has established building codes and design standards for buildings located within the city limits. The City of Los Angeles Building Code, Sections 91.000 through 91.7016 of the Los Angeles Municipal Code, regulates construction in the City of Los Angeles. Provided in these building codes are the requirements for construction, grading, excavations, use of fill, and foundation work, including design and material type. These codes are intended to limit the probability of the occurrence and severity of the impact from geologic hazards (i.e., earthquakes). Los Angeles Municipal Code also incorporates structural seismic requirements from the 2007 California Building Code (CBC).

City of Long Beach Building Codes. The Long Beach Building Codes established building codes and design standards for buildings located within the city limits. The Building Code is a section of the Long Beach Municipal Code. This requires that all construction conform to the seismic requirements in the State of California's 2007 California Building Code (CBC), as found in the Long Beach Building Code, Title 18.68.

City of Carson Building Codes. The Carson Building Codes titled the *Building Code of the City of Carson*, established building codes and design standards for buildings located within the city limits and adhere to the regulations in the 2007 CBC as adopted by the Los Angeles County Code, Title 26.

3.5.3.2 Regulations Pertaining to Mineral Resources

Surface Mining and Reclamation Act of 1975. SMARA was enacted to promote conservation of the State's mineral resources and to ensure adequate reclamation of lands once they have been mined. Among other provisions, SMARA requires the State Geologist to classify land in California for mineral resource potential. The four categories include: Mineral Resource Zone (MRZ)-1, areas of no mineral resource significance; MRZ-2, areas of identified mineral resource significance; MRZ-3, areas of undetermined mineral resource significance; and MRZ-4, areas of unknown mineral resource significance. The distinction among these categories is important for land use considerations.

The presence of known mineral resources that are of regional significance and possibly unique to that particular area could potentially result in non-approval or changes to a given proposed project if it were determined that those mineral resources would no longer be available for extraction and consumptive use. To be considered significant for the purpose of mineral land classification, a mineral deposit, or a group of mineral deposits that can be mined as a unit, must meet marketability and threshold value criteria adopted by the California State Mining and Geology Board. The criteria vary for different minerals depending on the following: (1) whether the minerals are strategic or non-strategic; (2) the uniqueness or rarity of the minerals; and (3) the commodity-type category (metallic minerals, industrial minerals, or construction materials) of the minerals. The State Geologist submits the mineral land classification report to the State Mining and Geology Board, which transmits the information to appropriate local governments that maintain jurisdictional authority in mining, reclamation, and related land use activities. Local governments are required to incorporate the report and maps into their general plans and consider the information when making land use decisions.

3.5.4 Impacts and Mitigation Measures

3.5.4.1 Methodology

The potential impacts on the proposed Project and alternatives have been evaluated with respect to the geologic environment and soils, and will be addressed in two ways: 1. evaluation of the impacts of the proposed Project on the local geologic environment; and 2. impacts of geohazards related to the proposed Project that may result in damage to structures, infrastructure, or exposure of the population to substantial risk of injury.

3.5.4.2 Thresholds of Significance

Significance criteria presented below are based on Appendix G of the CEQA Guidelines and on the Los Angeles CEQA Thresholds Guide (City of Los Angeles, 2006), and are used to determine the significance of the impacts on the proposed Project as related to geology and soils.

An impact is considered significant if it has the potential to result in a substantial adverse effect to structures or people, including substantial damage to structures or infrastructure or exposure of the population to substantial risk of injury as a result of a geological hazard. Because the region is considered to be geologically active, most projects are exposed to some risk from geologic hazards. These hazards are designated below and include:

GEO-1 Fault surface rupture, ground shaking caused by seismic activity, liquefaction, or other seismically induced ground failure;

GEO-2 Tsunamis or seiches;

GEO-3 Subsidence or settlement of the land surface;

GEO-4 Expansive soils;

GEO-5 Earth movement or slides including landslides, rockslides, or mudflows; or

GEO-6 Unstable soil conditions caused by human activities including excavation, grading, or fill.

A project may also have a significant impact on landforms or mineral resources if it has the potential to result in the:

GEO-7 Destruction, permanent coverage, material or adverse modification of one or more distinct and prominent geologic topographic features. Examples of such features may include hilltops, ridges, hill slopes, canyons, ravines, rock outcrops, water bodies, streambeds, and wetlands. However, other similar features may be affected.

GEO-8 Substantial erosion or loss of topsoil.

One additional criterion related to mineral resources was determined in the NOP not to be relevant to the proposed Project and is not considered in this document. This methodology is consistent with CEQA Guidelines Section 15063(c)(3). Consistent with CEQA Guidelines Section 15128, a copy of the Notice of Availability, including the initial study, is made available in Appendix A. The following section discusses the threshold categories as related to construction and operational activities of the proposed Project and alternatives.

3.5.4.3 Impacts and Mitigation Measures

The assessment of potential impacts is based in part on compliance with federal, state, and local regulatory requirements established by the Cities of Los Angeles, Long Beach, and Carson, and on the following assumptions:

1. BNSF would design and construct improvements in accordance with established building codes (see Section 3.5.3.1.2) that incorporate structural seismic requirements of the California Uniform Building Code, to minimize impacts associated with seismically induced geohazards. It is the intent of these codes to limit the probability of occurrence and the severity of consequences from geological hazards. Provided in these codes and criteria are requirements for construction, grading, excavations, use of fill, and foundation work, including type of materials, design, procedures, etc.
2. Design would incorporate the findings related to seismic hazards of the geotechnical evaluation report generated from a detailed subsurface investigation and related testing of subsurface materials.
3. BNSF would obtain all necessary permits, plan checks, and inspections.
4. Project engineers would review the Project plans for compliance with the appropriate standards in the building codes.
5. In addition, BNSF would ensure that emergency plans and procedures are incorporated into construction and operations in order to lessen the severity of the consequences of seismic events. Plans would include training and procedures for worker and visitor notification and evacuation.

Impact GEO-1: Seismic activity along the Palos Verdes and Newport-Inglewood faults, as well as other regional faults, would have the potential to produce fault rupture, seismic ground shaking, liquefaction, or other seismically induced ground failure but would not expose the population and structures to substantial risk from construction and operation of the proposed Project.

Based on the proximity of the Project site to known active faults, it is reasonable to expect that a strong ground motion seismic event (earthquake) may occur during the lifetime of the proposed Project. Such an event would result in an increase in exposure of the population and structures to seismic hazards. The impacts from a seismic event may be amplified due to the presence of water-saturated subgrade materials. Under Los Angeles Municipal Code, the Project site (and surrounding areas) lies within Seismic Zone 4. This zone designation is the most severe.

The Project site presently includes a number of structures, including warehouses, maintenance facilities, and small office buildings, most of which were built several decades ago in conformance with older building codes. The three California Cartage Company warehouses, which total approximately 600,000 sq ft of covered area, are by far the largest and oldest structures on the site, having been built in the 1940s (see Section 3.4.2.5.3). These structures can be assumed to be more vulnerable to seismic events than newer structures built to modern codes would be. Construction of the proposed Project would involve demolishing all of the existing structures, which would be even less resistant to seismic effects while they are partially demolished. Similarly, projects in construction phases are especially susceptible to earthquake damage because they are more likely not to be in a condition to withstand intense ground shaking. If an earthquake were to occur during demolition or construction, the compromised structural integrity could increase the risk of damage to the structures and hazards to construction workers.

During operation, the new structures and infrastructure, like all structures in the region, would be vulnerable to seismic activity. As discovered during previous earthquakes in this region (e.g., the 1971 San Fernando earthquake and the 1994 Northridge earthquake), existing building codes are sometimes inadequate to completely protect engineered structures during operation from hazards associated with liquefaction, ground rupture, and large ground accelerations. This means that designing new facilities based on existing building codes may not prevent significant damage to structures from earthquakes on any of the regional faults. In the event of a major earthquake structures would be expected to suffer some damage, possibly including minor structural damage, but would not fail. In a great quake (magnitude 8.0 or greater) many structures would suffer structural damage, although widespread collapse would not be expected. In any event, the new structures of the proposed Project are assumed to be more resistant to ground shaking events than the existing ones because they would be constructed in accordance with more modern building codes than was the case for the existing buildings.

The SCIG facility and the relocated facilities on the site would all have emergency response and evacuation plans that would include contingencies for earthquake preparedness, which would reduce the risk of injury to on-site personnel in the event of an earthquake. As an example, BNSF represents that its facilities have contingency plans that identify emergency response actions and evacuation procedures (see Section 3.7 for more detail on the contents of emergency plans).

Given the modern construction of the new facilities and the implementation of emergency planning, operation of the proposed Project would not increase, and would likely reduce, the risk of damage and injury resulting from seismic activity compared to baseline conditions.

Impact Determination

As stated previously, seismic activity along mapped local and regional faults would potentially produce fault rupture, seismic ground shaking, liquefaction, or other seismically induced ground failure. The seismic hazards common to the area and characteristic of baseline conditions would not be increased by construction or operation of the proposed Project. However, because strands of active faults are located near the Project area, and the area is mapped within an area of historic liquefaction, there is potential for substantial risk of seismic impacts. Incorporation of modern construction engineering and safety standards and compliance with building codes adopted by the local regulatory bodies would minimize impacts due to seismically induced ground failure. The probability of an earthquake large enough to damage structures occurring during the construction phase is considered to be low.

During operation, the modern construction of buildings and other structures would reduce the risk of injury in the event of an earthquake. Emergency planning and coordination would also contribute to reducing injuries to on-site personnel during a seismic activity. With incorporation of emergency planning and compliance with current building regulations, damage and/or injury may occur, and impacts due to seismically induced ground failure would be less than significant.

Mitigation Measures

No mitigation measures are required.

Residual Impacts

Less than significant impact.

Impact GEO-2: Construction and operation of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from tsunamis and seiches.

As described in Section 3.5.2.5, there is only a remote probability that tsunamis or seiches would cause substantial damage to structures or injuries to persons in the proposed Project area. According to several studies (e.g., Synolakis et al, 1997, Legg et al., 2004, Moffat & Nichol, 2007) the frequency of tsunamigenic earthquake events was estimated at every few hundred to a few thousand years, meaning that the probability of such an event occurring during the assumed 34-year span of the proposed Project (construction and operation) is low. Were such an event to occur, the maximum estimated water level would be approximately 0 to 3 feet at the coastline one-half mile south of the proposed Project area, meaning that water levels would be less than that at the Project site. Based on these studies, the potential for tsunami-induced flooding to affect the proposed Project area is very low. Ongoing and future climate change may alter the potential for flooding at the site by altering sea level and the frequency and severity of storms. Because climate change in the context of CEQA is linked to greenhouse gas emissions, this issue is addressed in Section 3.6, Greenhouse Gases.

Impact Determination

The proposed Project area is approximately one-half mile north and inland of an area of potential tsunami impact. Given that the projected water level rise from tsunami-induced flooding would be 3 feet or less at that point of impact, that the attenuation of the wave from that point to the Project site would further reduce the water level rise, and that the event that could produce such a tsunami is very rare, the likelihood of tsunami-induced flooding, and subsequent damage, at the proposed Project site is remote. Accordingly, impacts would be less than significant.

Mitigation Measures

No mitigation is required.

Residual Impact

Less than significant impact.

Impact GEO-3: Construction and operation of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from subsidence/soil settlement.

Subsidence resulting from previous oil extraction in the Port area has been mitigated (Port of Los Angeles, 2007) and is no longer a potential source of risk to existing structures (i.e., baseline conditions) or future development projects, including the proposed Project.

As described in Section 3.5.2.9, compressible soils may be encountered on the Project site during construction. While compressible soils would not have substantial adverse effects during the construction phase, without proper engineering structures could eventually become distressed due to settlement of unconsolidated/compressible soils, representing an adverse effect on Project operations.

The Project design process includes a site-specific geotechnical investigation to evaluate all areas where structures are proposed to assess their potential to be affected by settlement of onsite soils. The investigation includes subsurface soil sampling, geotechnical laboratory analysis of samples collected to evaluate the compressibility of soils, and compilation and engineering analysis by the Project engineer. The recommendations provided in the geotechnical investigation report would be incorporated into the design plans and specifications for the proposed Project and would be consistent with City design guidelines, including Sections 16 91.000 through 91.7016 of the Los Angeles Municipal Code, in conjunction with criteria established by LAHD and Caltrans. For areas with soils subject to settlement, typical recommendations would include overexcavation and recompaction of compressible soils.

Impact Determination

Geotechnical engineering would substantially reduce the potential for soil settlement and would ensure that construction and operation of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury as a result of subsidence and soil settlement. Accordingly, impacts would be less than significant.

Mitigation Measures

No mitigation is required.

Residual Impacts

Less than significant impact.

Impact GEO-4: Construction and operational activities related to the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from soil expansion.

Expansive soils are not anticipated to be encountered in native soils in the proposed Project area. However, expansive soils that may be present in soils imported to the proposed Project site during construction activities could, without proper engineering, subject proposed structures to structural distress. However, during Project design, the Project engineer would evaluate all areas where structures are proposed for their potential to be affected by expansive soils. The site-specific geotechnical investigation would include subsurface soil sampling, geotechnical laboratory analysis of samples collected to evaluate the expansion potential of the soils, and compilation and engineering analysis by the Project engineer. The recommendations provided in the geotechnical investigation report would be incorporated into the design plans and specifications for the proposed Project and would be consistent with City design guidelines, including Sections 16 91.000 through 91.7016 of the Los Angeles Municipal Code, in conjunction with criteria established by LAHD and Caltrans. For sites with soils subject to expansion, typical recommendations include overexcavation and replacement of expansive soils, which would allow for construction of a conventional slab-on-grade. Alternative recommendations may include the use of post-tensioned slabs in construction or structures may be founded using concrete or steel foundation piles through the expansion-prone soils to non-expansive soils.

Impact Determination

Geotechnical engineering as outlined above would substantially reduce the potential for soil expansion and would ensure that the proposed Project would not result in substantial damage to structures or infrastructure during construction and operation, or expose people to substantial risk of injury. Accordingly, impacts from the proposed Project resulting from expansive soils would be less than significant.

Mitigation Measures

No mitigation is required.

Residual Impacts

Less than significant impact.

Impact GEO-5: Construction and operation of the proposed Project would not result in or expose people or property to a substantial risk of earth movement or slides including landslides, rockslides or mudflows.

As described in Section 3.5.2.7, the proposed Project area is located on a flat site and is not subject to earth movement or slides including landslides, rockslides, or mudflows.

Impact Determination

Because the proposed Project site and surrounding area would not be subject to earth movement, slides, or mudflows, no impacts would occur.

Mitigation Measures

No mitigation is required.

Residual Impacts

No impact.

Impact GEO-6: Shallow groundwater, which would cause unstable soil conditions, may be encountered during demolition and construction, but would not expose people or structures to substantial risk of injury or damage.

Natural alluvial and estuarine deposits, as well as artificial fill, may be encountered during excavations and other ground disturbing activities during construction. Groundwater may be present at shallow depths: as described in Section 3.12.2.1, the depth to groundwater beneath the proposed Project is approximately 10 feet. Excavations for underground utility construction, foundations, or vehicle maintenance pits, would be expected to encounter groundwater. Soils near and below the groundwater level can be expected to behave in a fluid-like manner. This would result in the requirement for implementation of engineering practices regarding saturated, collapsible soils. Such practices may include dewatering wells and similar special handling procedures to facilitate excavation. For example, dewatering wells would locally increase the depth to groundwater, thus reducing the potential for collapsible soils to affect construction activities. Temporary shoring could also be utilized to stabilize excavations in saturated, collapsible soils.

Impact Determination

The use of standard engineering practices regarding unstable soils would prevent the exposure of people or structures to substantial adverse effects during construction and operational activities at the proposed Project. Therefore, impacts associated with unstable soil conditions would be less than significant.

Mitigation Measures

No mitigation is required.

Residual Impacts

Less than significant impact.

Impact GEO-7: Construction and operation of the proposed Project would not cause destruction, permanent coverage, material or adverse modification to one or more distinct and prominent geologic topographic features.

Since the proposed Project area is relatively flat, with no prominent geologic or topographic features, proposed Project construction would not result in any distinct and prominent geologic or topographic features being destroyed, permanently covered, or materially and adversely modified.

Impact Determination

Because no prominent geologic or topographic features would be adversely affected by construction or operation of the proposed Project, there would be no impacts.

Mitigation Measures

No mitigation is required.

Residual Impacts

No impact.

Impact GEO-8: Construction and operation of the proposed Project would not result in substantial erosion or loss of topsoil.

Construction activities and the alteration of landforms could, if they take place on sloping ground, cause wind-related erosion that would remove topsoil from the site. However, the proposed Project is located on an essentially flat site that would not be susceptible to substantial erosion. Topsoil on the site consists of artificial fill and recent alluvial deposits that have been disturbed by decades of development. Construction activities would expose bare ground that would be subjected to a degree of erosion during storm events, but the implementation of storm water controls (see sections 2.4.3.1 and 3.12.4.1) would minimize the loss of topsoil. During operations, the SCIG site and relocation sites would be largely paved; exposed soil would be confined to landscaped areas, and the likelihood of substantial erosion would be small.

Impact Determination

Because the Project site is flat, erosion controls would be in place during construction, and the Project site would be largely paved once construction was complete, impacts related to erosion and the loss of topsoil would be less than significant.

Mitigation Measures

No mitigation is required.

Residual Impacts

Less than significant impact.

3.5.4.4 Summary of Impact Determinations

Table 3.5-2 summarizes the impact determinations associated with the proposed Project related to Geology and Soils. Identified potential impacts may be based on federal, state, or city significance criteria, and the scientific judgment of the report preparers.

For each type of potential impact, the table describes the impact, notes the impact determinations, describes any applicable mitigation measures, and notes the residual impacts (i.e.: the impact remaining after mitigation). All impacts, whether significant or not, are included in this table.

3.5.4.5 Mitigation Monitoring

No mitigation monitoring is required.

3.5.5 Significant Unavoidable Impacts

There would be no significant and unavoidable impacts as a result of construction and operation of the proposed Project.

Table 3.5-2. CEQA Impact Determinations of the Proposed Project and Alternatives.

Environmental Impacts	Impact Determination	Mitigation Measures	Residual Impacts after Mitigation
GEO 1: Seismic activity along the Palos Verdes and Newport-Inglewood faults as well as other regional faults has the potential to produce fault rupture, seismic ground shaking, liquefaction, or other seismically induced ground failure that would expose the population and structures to substantial risk.	Less than significant impact	Mitigation not required	Less than significant impact
GEO 2: Construction and operation of the proposed Project would not expose people and structures to substantial risk of injury or damage from tsunamis and seiches.	Less than significant impact	Mitigation not required	Less than significant impact
GEO 3: Construction and operation of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from subsidence/soil settlement.	Less than significant impact	Mitigation not required	Less than significant impact

Environmental Impacts	Impact Determination	Mitigation Measures	Residual Impacts after Mitigation
GEO 4: Construction and operation of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from soil expansion.	Less than significant impact	Mitigation not required	Less than significant impact
GEO 5: Construction and operation of the proposed Project would not result in or expose people or property to a substantial risk of earth movement or slides including landslides, rockslides or mudflows.	No impact	Mitigation not required	No impact
GEO 6: Shallow groundwater, which would cause unstable soil conditions, may be encountered during demolition and construction, but would not expose people or structures to substantial risk of injury or damage.	Less than significant impact	Mitigation not required	Less than significant impact
GEO 7: Construction and operation of the proposed Project would not cause destruction, permanent coverage, material or adverse modification to one or more distinct and prominent geologic topographic features.	No impact	Mitigation not required	No impact
GEO 8: Construction and operation of the proposed Project would not result in substantial erosion or loss of topsoil.	Less than significant impact	Mitigation not required	Less than significant impact