# 3.5

## GEOLOGY AND SOILS

# 3.5

# GEOLOGY AND SOILS

## 3.5.1 Introduction

This section describes the existing conditions and applicable regulations for geology and soils, and analyzes proposed project impacts related to: (1) seismic hazards, including surface rupture, ground shaking, liquefaction, tsunamis, and seiches; (2) other geologic issues, including subsidence, potentially unstable soils and slopes; and (3) mineral resources.

The existing conditions and subsequent analysis are based on published reports, both regional in scope and proximal to the proposed project site, as indicators of potential geologic hazards. During construction and operation, compliance with the applicable building codes would ensure the proposed Project would not result in a significant geology and soils impact. No mitigation is required.

## 3.5.2 Environmental Setting

This section describes the regional and local geologic conditions surrounding the proposed project site. The information is derived from regional and proposed project area-wide geologic maps and literature, as well as reports developed for projects within the Los Angeles Harbor.

The surface of the proposed project site varies from about 5 to 14 feet above mean sea level (AMSL; USGS 1981), and the adjacent Main and East Channels had a water depth of approximately 45 to 53 feet in 2003 (MXSOCAL 2011). Harbor depths increase to the south. This general configuration has been in place since at least 1925 (USGS 1925 [surveyed in 1923], Wilmington quadrangle).

### 3.5.2.1 Regional and Local Setting

The proposed project site is located near sea level in the coastal area of the Los Angeles Basin, a southward sloping plain bordered on the inland margins by the Santa Monica Mountains to the north, the Repetto and Puente Hills to the northeast, the Santa Ana Mountains to the east, and the San Joaquin Hills to the southeast. The Los Angeles Basin is bordered on the south and west by the Pacific Ocean/San Pedro

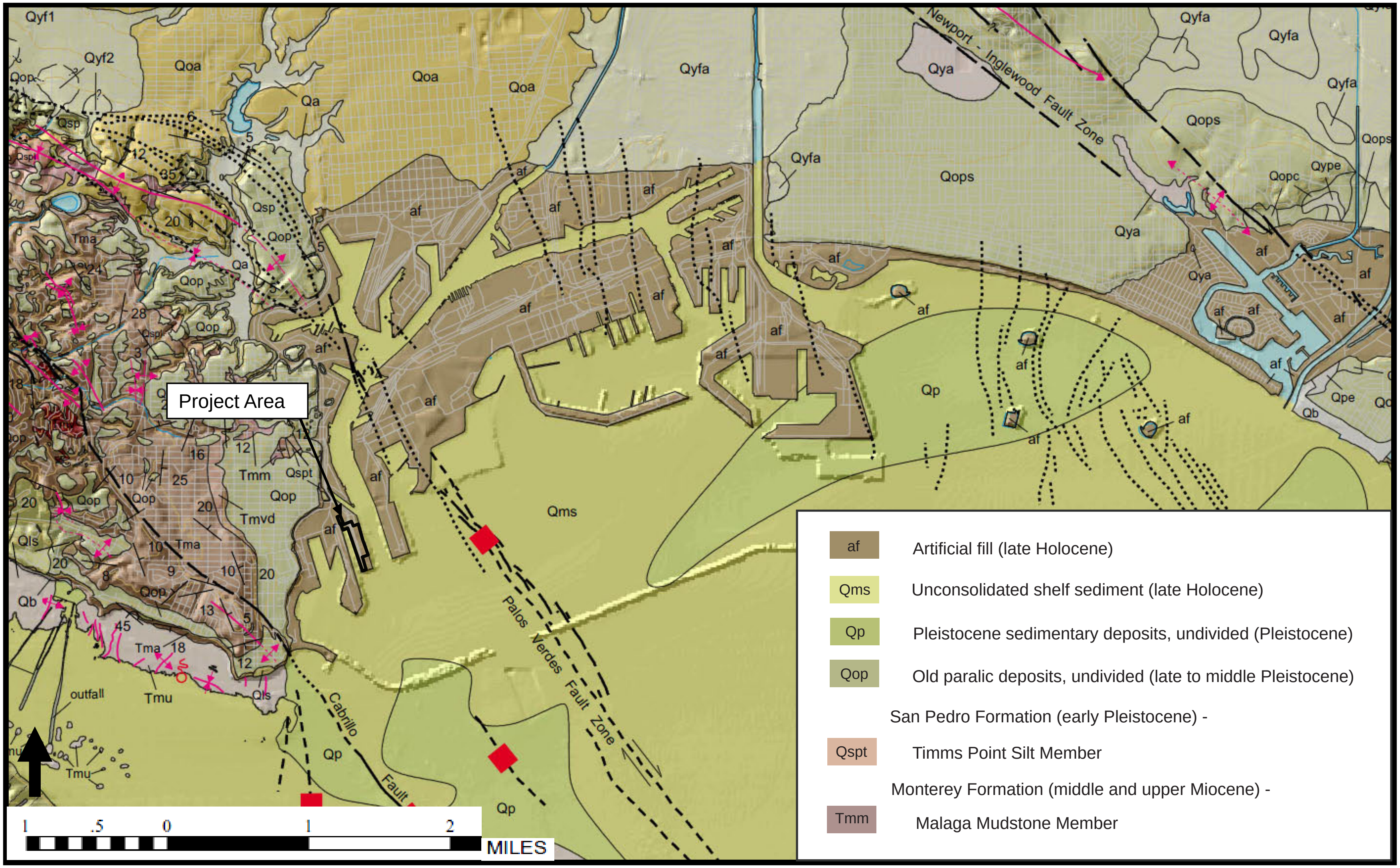
Shelf and the Palos Verdes Hills. The proposed project site is on the San Pedro Shelf, which was just offshore of the southeast Palos Verdes Hills prior to development of the Los Angeles Harbor.

The Los Angeles Basin is underlain by numerous crystalline and sedimentary bedrock formations and is filled with younger alluvial deposits varying from several tens to several hundreds of feet thick. Tertiary-age bedrock (e.g., Monterey Formation [map symbol Tm]) forms the Palos Verdes Hills west and north of the proposed project site, with Quaternary-age alluvial deposits (e.g., paralic deposits [Qop] and Timms Point silt [Qspt]) covering the lower-lying surfaces around the hills (Figure 3.5-1; Saucedo et al. 2003). Within the Los Angeles Harbor there are Holocene-age, near-shore and marine deposits (Qms), including beach, estuary, tidal flat, lagoon, shallow-water bay sediments, and Quaternary sedimentary deposits (Qp), both often overlain by anthropogenic (made or caused by humans) artificial fill (af).

Surficial geologic materials in the immediate vicinity of the proposed project site are characterized by Holocene-age, near-shore to shallow water marine deposits (map symbol Qms on Figure 3.5-1; Saucedo et al. 2003). Deposits likely include relatively fine-grained beach, estuary, tidal flat, lagoon, and shallow-water bay sediments underlain by older Quaternary deposits (Qspt and/or Qop). Quaternary alluvium deposits are a heterogeneous mixture of predominantly soft to hard silts and clays, intermixed with sandy soils (Diaz-Yourman & Associates 2004). Existing facilities are founded on anthropogenic artificial fill placed during dredging and filling operations within the Los Angeles Harbor area. The fill is a mix of the surrounding native Qms deposits that have suitable to very poor engineering properties. A majority of these hydraulically and conventionally placed fills should be considered non-engineered and uncertified. Such fills generally consist of loose to dense, coarse- to fine-grained sands, and soft to firm silts and clays (Diaz-Yourman & Associates 2004).

In addition to Diaz-Yourman & Associates' (2004) geotechnical assessment of the San Pedro Waterfront and Promenade, several other geotechnical reports were reviewed for earlier projects to the east and south of the proposed project site. These projects and the existing development at the proposed project site were completed in the same general time frame. This suggests that the placement of artificial fill materials and rip-rap/armor rock as described in the earlier projects would be very similar to what was done at the proposed project site. It is anticipated that, pending necessary proposed project area–specific studies, these earlier studies are representative of proposed project site conditions.

A geotechnical report (Lockwood-Singh & Associates 1985) for the "Proposed Yacht Club and Commercial Building, 22nd Street, Parcel F" approximately 1,500 feet west of the proposed project site encountered 7 to 30 feet of artificial fill over native alluvium. Fill consisted of moderately firm/stiff silty clay, sandy silt, and silty sand to depths of 40 to 60 feet below ground surface (bgs). Native alluvium consisted of soft (upper 4 to 5 feet) and firm to stiff clayey silt and silty clay with rock fragments and fine-grained sand lenses. Groundwater was measured at 7 to 17 feet bgs during the preparation of the 1985 report.




Source: USGS, Saucedo and others, 2003

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**Figure 3.5-1**
**Geologic Formations**
**City Dock No. 1 Marine Research Center Project**

Berths 51 through 55 immediately west of the proposed project site were investigated in 1960 (Dames & Moore) for wharf reconstruction. The wharf was constructed on artificial fill contained by granitic rip-rap and on marine sediments; the rip-rap (encountered 8 to 17 feet thick) formed a 1.5:1 (horizontal to vertical) slope away from the wharf toward the channels. Marine sediments consisted of silts and sands over organic silt containing minor sand lenses, and some non-continuous basaltic gravel, cobble, and boulder layers at depths ranging from approximately 43 to 72 feet.

Due south of the earlier Dames & Moore investigation, Berth 49 was investigated in 1976 by Converse Davis Dixon Associates due to “land slippage” resulting in several feet of lateral (to 14 feet) and vertical (to 5 feet) movement at the site. It was determined that in general the subsurface units consisted of 30 feet of hydraulic fill (soft to stiff clayey silt and silty clay) contained by a “quarry muck dike” and armor rock, 5 feet of natural marine deposits (dense silty sand, possibly Qspt), and underlying Malaga Mudstone (Tmm) bedrock. The study concluded that soft Malaga Mudstone bedrock dipped generally to the east and that excessive stockpiling of iron ore on the wharf caused downward pressure on a weak bedding plane initiating a bedding plane failure and the slippage described.

Between the Lockwood-Singh study area and the Dames & Moore study area, Diaz-Yourman & Associates (2008) performed a geotechnical investigation for the Cabrillo Way Marina Development Project. Using borings and cone penetration testing methods it was determined that the site deposits consisted of fill material, possibly underlain by natural alluvial deposits, which in turn were underlain by the Malaga siltstone. Fill and natural alluvial materials could not be easily separated and consisted of a heterogeneous mixture of predominantly soft to firm silts and clays, with loose to medium dense sandy soils extending to depths of 20 to 30 feet bgs.

Diaz-Yourman & Associates reviewed of historic topographic/bathymetric maps and concluded that immediately west (shoreward) from the proposed project site, the Cabrillo Way Marina site was under water in 1859 and was filled to its present elevation by 1930. Based on this information and the drilling data from the three projects near the proposed project site, it is estimated that artificial fill materials beneath the proposed project site may be a minimum of 30 feet thick and should be contained by large granitic rip-rap materials. The fill is likely underlain by several feet (at least 4 to 5 feet) of native marine sediments. Underlying these materials is Malaga Mudstone (Tmm). Since specific soil descriptions and thicknesses are interpreted from geotechnical borings drilled in the studies near the proposed project site, these preliminary conclusions should be considered for planning (not design) purposes.

## 3.5.2.1.1 Geologic Hazards

### 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 magnitude

(M) represents a tenfold increase in the wave magnitude generated by an earthquake. A M8.0 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). Structure damage typically begins at M5.0. A limitation of the Richter magnitude scale is that at the upper limit large earthquakes have about the same magnitude. As a result, the Moment Magnitude Scale, which does not have an upper limit magnitude, was introduced in 1979 and is often used for earthquakes greater than M3.5. Earthquakes of M6.0 to 6.9 are typically classified as moderate; those between M7.0 and M7.9 are classified as major; and those of M8.0 or greater are classified as great.

The southern half of California is recognized as one of the most seismically active areas in the United States. The region has been subjected to at least 50 earthquakes of M6 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. Large earthquakes, such as the 1857 Fort Tejon earthquake on the San Andreas Fault, are rare in southern California. Earthquakes of M≥7.5 are expected to have an average probability of 37% in a 30 year period. This average probability is 97% for earthquakes of M≥6.5 (USGS Working Group on California Earthquake Probabilities 2008). Table 3.5-1 lists selected earthquakes that have caused damage in the Los Angeles Basin.

**Table 3.5-1.** Large Earthquakes in the Los Angeles Basin Area

| *Fault Name* | *Place* | *Date* | *Moment Magnitude* |
|---|---|---|---|
| Palos Verdes | a | a | a |
| San Pedro Basin | a | a | a |
| Santa Monica-Raymond | a | 1855 | 6.0 |
| San Andreas | Fort Tejon<br>Kern County | 1857<br>1952 | 8.2b<br>7.7 |
| Newport-Inglewood | Long Beach | 1933 | 6.3 |
| San Fernando/Sierra Madre-Cucamonga | San Fernando<br>Sierra Madre | 1971<br>1991 | 6.7<br>5.8 |
| Whittier-Elsinore | Whittier Narrows | 1987 | 5.9 |
| Camp Rock/Emerson | Landers | 1992 | 7.3 |
| Blind Thrust Fault beneath Northridge | Northridge | 1994 | 6.7 |

[a] No known earthquakes within the last 200 years.

[b] Approximate magnitude

Source: LAHD 2008 (modified with USGS 2011 and SCEC 2011)

Seismic analyses may include discussions of the maximum earthquakes that specific faults are considered capable of generating without considering the probability of occurrence. The concept of maximum probable earthquake indicates an earthquake having a 10% probability of being exceeded in 50 years, which corresponds to an earthquake return period of approximately 475 years. The Port uses a combination of probabilistic and deterministic seismic hazard assessments for seismic design. Probabilistic hazard assessments are required to define two design-level events, the Operational Level Earthquake (OLE) design event, which generates ground acceleration with a 50% probability of exceedance in 50 years, and the Contingency Level Earthquake (CLE), which generates ground acceleration with a 10% probability of exceedance in 50 years.

Numerous significant earthquake-generating active faults and fault zones are located within the general region, such as the Newport-Inglewood, Whittier-Elsinore, Santa Monica, Hollywood, Malibu Coast, Raymond, San Fernando, Sierra Madre, Cucamonga, San Jacinto, and San Andreas Faults. Table 3.5-2 lists these potentially significant faults in the Los Angeles Basin area and their estimated maximum moment magnitudes. Active faults, such as those noted in Table 3.5-2, are typical of southern California.

**Table 3.5-2.** Major Regional Faults

| *Fault* | | *Maximum Moment Magnitude (Mw)* | *Fault Type* | *Slip Rate (mm/yr)* | *Source Type* | *Approximate Distance from SPW in Miles (kilometers)* |
|---|---|---|---|---|---|---|
| Palos Verdes | | 7.3 | SS | 3 | B | 0 (0) |
| Newport-Inglewood | | 7.1 | SS | 1 | B | 6.7 (10.8) |
| Whittier-Elsinore | | 6.8 | SS | 2.5 | A | 22.0 (35.5) |
| Malibu-Santa Monica-Raymond Fault Zone | Santa Monica | 6.6 | DS | 1 | B | 27.7 (36.7) |
| | Hollywood | 6.4 | DS | 1 | B | 24.2 (39.0) |
| | Malibu Coast | 6.7 | DS | 0.3 | B | 24.3 (39.2) |
| | Raymond | 6.5 | DS | 1.5 | B | 25.8 (41.6) |
| Cucamonga | | 6.9 | DS | 5 | A | 40.7 (65.6) |
| San Jacinto | | 6.7 | SS | 12 | A | 55.7 (89.9) |
| San Andreas | | 7.4 | SS | 30 | A | 53.7 (86.7) |

Notes: DS = Dip slip; NT = Normal-Thrust; RO = Reverse Oblique; and SS = Strike Slip
Source: LAHD 2008 (from CDMG 1998c)

Other nearby, but less active, seismic sources include the Cabrillo Fault, San Pedro Basin Fault, the Compton blind thrust, and the Los Alamitos Fault. These are considered in the overall assessment of potential ground shaking levels within the Port (Earth Mechanics, Inc. 2006).

In accordance with the Alquist-Priolo Act of 1974, the California Division of Mines and Geology (CDMG) was directed to delineate those faults deemed active and likely to rupture the ground surface. No faults within the area of the Port are currently zoned under the Alquist-Priolo Act; however, there is evidence that the Palos Verdes

Fault, which lies east of the proposed project site, is active and the potential for ground rupture cannot be ruled out (Fischer et al. 1987; McNeilan et al. 1996). The basis for the location of the Palos Verdes Fault Zone as shown within the Port (and its exclusion from other areas), as stated by Earth Mechanics, Inc. (2006), is that the fault zone is well defined to the south by seismic-reflection data, which suggests seafloor and shallow subsurface disruption of young sediments. Figure 3.5-2 presents the faults and geologic fold structures in the proposed project area.

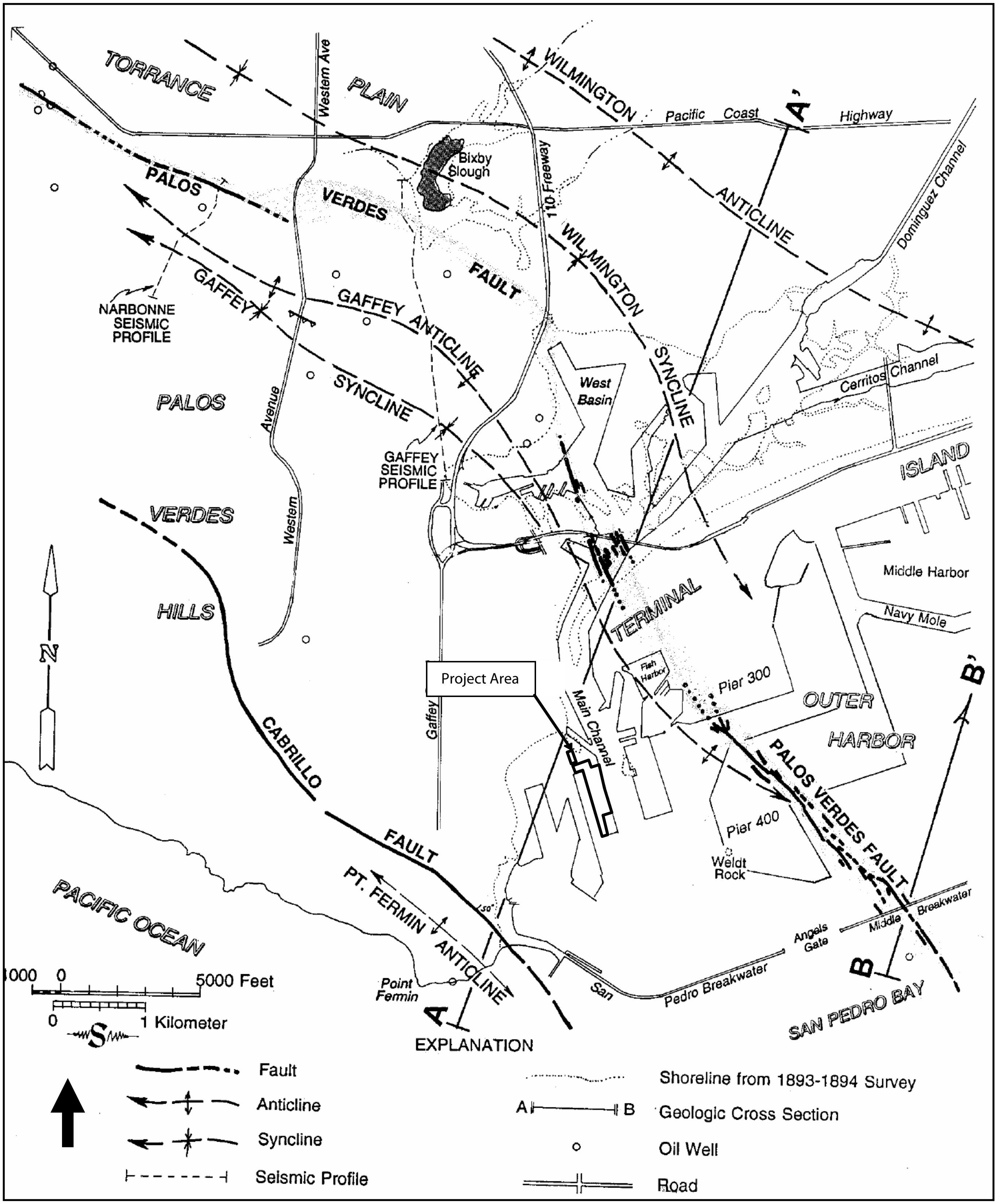
The active Palos Verdes Fault is the most important fault in terms of proposed project site development. Segments of the active Palos Verdes Fault Zone cross the Los Angeles Harbor east of the proposed project site. The presence and absence of the Palos Verdes Fault Zone in this general area of the harbor is based largely on numerous offshore seismic reflection geophysical profiles (Earth Mechanics, Inc. 2006) completed for various purposes. Current data suggest that segments of the fault may pass within approximately 0.7 mile east of the proposed project site (Earth Mechanics, Inc. 2006; Figure 3.5-3). Recent studies indicate that the Palos Verdes Fault Zone is capable of producing an earthquake of M6.7 to M7.2, and peak ground accelerations in the Port area of 0.23g (g = acceleration due to gravity) and 0.52g for the OLE and CLE, respectively. The potentially active Cabrillo Fault is located approximately 1 mile southwest of the proposed project site. It is also considered an important local fault because it may be a segment or branch of the Palos Verdes Fault and capable of producing an earthquake of M6.25 to M6.5 (Earth Mechanics, Inc. 2006).

Numerous active faults outside the Port are also capable of generating earthquakes that could affect the proposed project area (see Tables 3.5-1 and 3.5-2). The Newport-Inglewood Fault Zone, which was the source of the 1933 Long Beach M6.4 earthquake, is important due to its substantial length and relative proximity (7.3 miles) to the proposed project site. Large events could occur on more distant faults in the general area, but given their greater distance from the site, earthquakes generated on these faults are less significant with respect to ground accelerations.

## Liquefaction and Lateral Spreads

Soil liquefaction describes a phenomenon whereby a saturated soil substantially loses strength and stiffness in response to an applied stress, usually earthquake shaking or other sudden change in stress condition, causing it to behave like a liquid as a consequence of the loss of grain-to-grain contact due to increased pore pressure. Seismic ground shaking is capable of providing the mechanism for liquefaction, usually in fine-grained, loose to medium dense, saturated sands and silts. The effects of liquefaction may be substantial settlement and/or differential settlement of structures that overlie liquefiable soils, or possibly a lateral spread landslide. Lateral spread is a liquefaction-induced landslide of a fairly coherent block of soil and sediment deposits that move laterally (along the liquefied zone) by gravitational force, sometimes on the order of 10 feet, often toward a topographic low such as a depression or valley.

Some authors (Tinsley and Youd 1985) have indicated that the liquefaction potential in the harbor area during a major earthquake on either the San Andreas or Newport-




Source: Earth Mechanics Inc., 2006.

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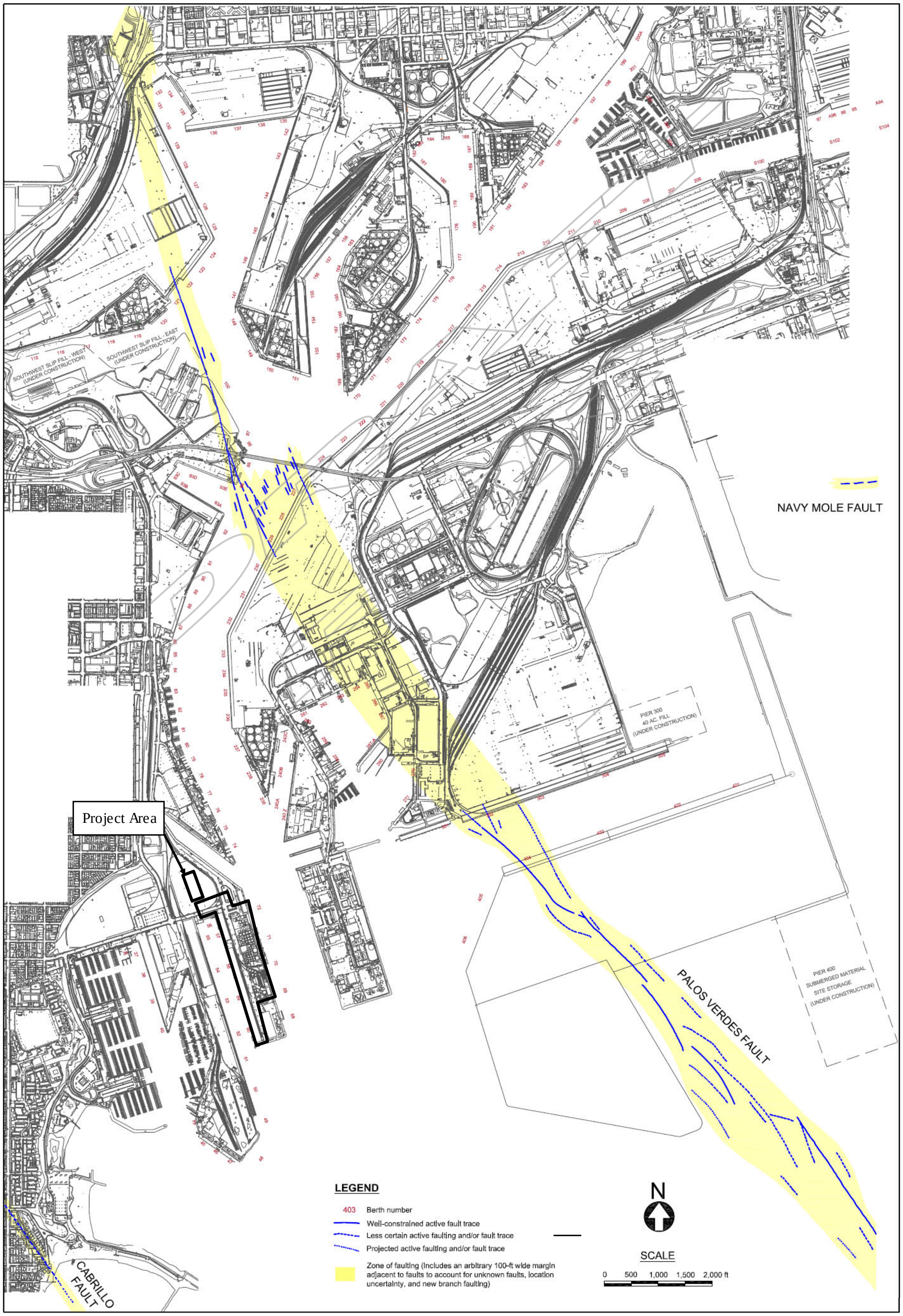
**Figure 3.5-2**
**Geologic Structure Map of the POLA Area**
**City Dock No. 1 Marine Research Center Project**




Source: Earth Mechanics Inc., 2006.

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**Figure 3.5-3**
**Palos Verdes Fault Zone**
**City Dock No. 1 Marine Research Center Project**

Inglewood Fault is high. The Seismic Hazards Zone Maps published by the State of California (Figure 3.5-4; CDMG 1999, 1998a, and 1998b) and the City of Los Angeles General Plan, Safety Element (City of Los Angeles 1996) show the site to be in an area susceptible to liquefaction because of the nature of the soils.

Former natural drainages and previous shallow bay/estuary environments at Port berths have been backfilled with non-engineered, uncertified artificial fill materials. Dredged materials from the Los Angeles Harbor area were spread across lower Wilmington from 1905 until 1910 or 1911 (Ludwig 1927). In many areas, rip-rap and armor rock were used to contain the fill to discrete areas, such as wharves. Natural alluvial deposits and marine sediments below the proposed project site are very likely unconsolidated, soft, and saturated, and contain varying amounts of sand, silt, and clay. Groundwater (seawater within the fill) is present at shallow depths beneath the proposed project site (depths ranging from 3 to 12 feet bgs). For more discussion of groundwater see Section 3.6, "Groundwater and Soils." The condition of the anthropogenic and natural materials, the saturation, and the area earthquake ground shaking potential are conducive to liquefaction.

### Expansive Soils

Expansive soils generally result from specific clay minerals that expand when saturated and shrink in volume when dry. These expansive clay minerals are common in the geologic units in the adjacent Palos Verdes Peninsula. Clay minerals in geologic units and previously imported fill soils at the proposed project site could have expansive characteristics.

### Subsidence

Subsidence is the phenomenon where the soils and other earth materials underlying a site settle or compress, resulting in a lower ground surface elevation. Fill and native materials beneath a site can be water saturated, and a net decrease in the pore pressure and contained water will allow the soil grains to pack closer together. This closer grain packing results in less volume and the lowering of the ground surface.

Subsidence in the LA/LB Harbors was first observed in 1928 and has affected the majority of the harbor area. Based on extensive studies by the City of Long Beach and the California Division of Oil and Gas and Geothermal Resources, it has been determined that most of the subsidence was the result of oil and gas production from the Wilmington Oil Field (discussed below) following its discovery in 1936, and the extraction of large volumes of groundwater for dry dock construction in the early 1940s. By 1945 subsidence of more than 4 feet was noted in the area of Long Beach Harbor (City of Long Beach 2006). By 1962 subsidence had spread over a wide area and reached approximately 26 feet in the area of Terminal Island (Parks 1999). Today, water injection continues to be maintained 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). Subsidence in the vicinity of the proposed Project, due to previous oil extraction in the Port area, has been mitigated and no longer poses a risk at the proposed project site; therefore, it is not discussed further.

### Landslides

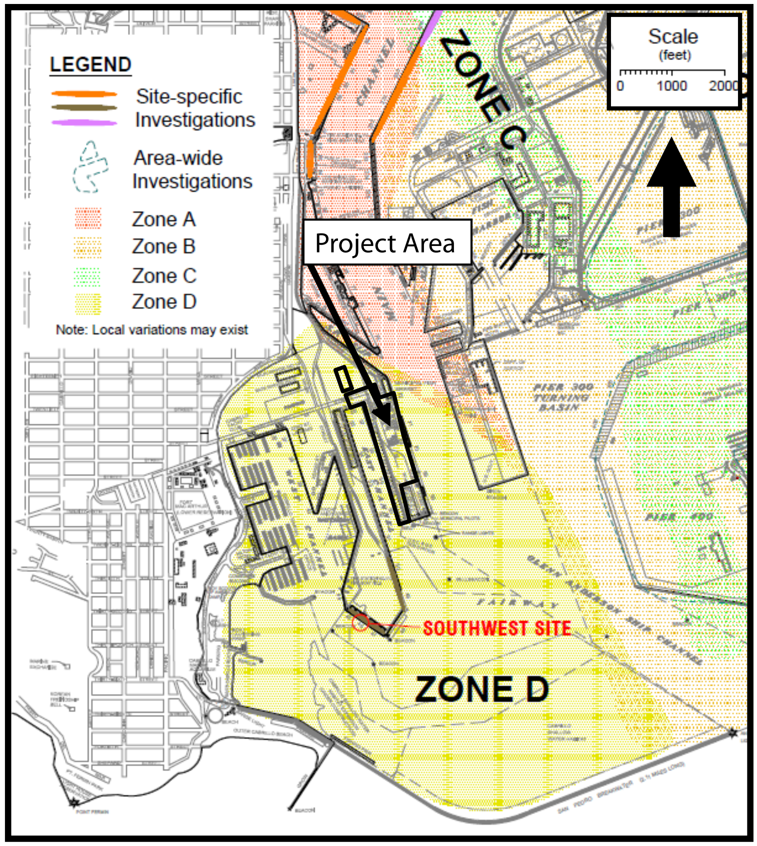
Generally, a landslide is defined as the downward and outward movement of loosened rock or earth on a hillside or slope. Landslides can occur either very suddenly or slowly, and frequently accompany other natural hazards such as earthquakes, floods, or wildfires. Most landslides are single events, but more than a third in the onshore environment are associated with heavy rains or the melting of winter snows. Landslides can also be triggered by ocean wave action or induced by the undercutting of slopes during construction, improper artificial compaction, saturation from sprinkler systems or broken water pipes, or surcharge of a landmass with potentially unstable conditions (e.g., out-of-slope bedding or weak materials). Immediate dangers from landslides include injuries or destruction of property on or above the landslide, and below the landslide from rocks, mud, and water sliding downhill. Other dangers include broken electrical, water, gas, and sewage lines. Due to its location offshore, no known or probable bedrock landslide areas have been identified at the proposed project site (City of Los Angeles 1996).

The 1976 geotechnical investigation by Converse Davis Dixon Associates at Berth 49 south and west of the proposed project site was prompted by “land slippage” resulting in several feet of lateral (to 14 feet) and vertical (to 5 feet) movement at the site. They concluded that soft, eastward dipping Malaga Mudstone weak bedding planes failed due to excessive downward pressure from stockpiling of iron ore on the wharf. Based on the nearby location of Berth 49, it is very possible that such a condition exists at the proposed project site and that a similar bedding plane failure is possible**.**

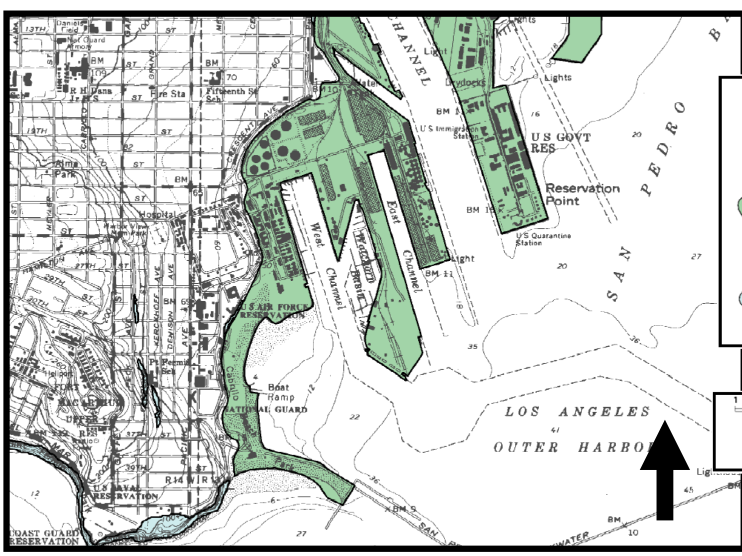
### Tsunamis

A tsunami is a long wavelength ocean wave generated by sudden displacement of the seafloor normally by earthquake faulting, volcanism, or a large submarine landslide. Transoceanic waves may have wavelengths of up to 125 miles and periods generally from 5 to 60 minutes. Initially the tsunami creates a drop in water level at the shoreline, followed by a rapid rise with attendant run up on the shore, surges into and out of shallow coastal inlets and harbors, and a substantial rise of water levels in deeper water ports and 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.

Until the last several years, projected tsunami run-ups along the western U.S. were based on far-field events, such as submarine earthquakes or landslides occurring at great distances from the U.S. An example is the Chilean earthquake of May 1960 that caused local damages of over $1 million and harbor closure, with maximum water level fluctuations recorded by gauges of 5.0 feet at Berth 60 (Moffat and Nichol 2007). Based on such distant sources, tsunami-generated wave heights of between 6.5 and 8 feet above MLLW, at 100-year intervals, and between 10 and 11 feet, at 500-year intervals, were projected, including the effects of astronomical tides (Houston 1980).




Soil Zones Used for Seismic Response Analysis




Potential Liquefaction Areas

**MAP EXPLANATION**

**Zones of Required Investigation:**

**Liquefaction**
Areas where historic occurrence of liquefaction, or local geological, geotechnical and groundwater conditions indicate a potential for permanent ground displacements such that mitigation as defined in Public Resources Code Section 2693(c) would be required.

**Earthquake-Induced Landslides**
Areas where previous occurrence of landslide movement, or local topographic, geological, geotechnical and subsurface water conditions indicate a potential for permanent ground displacements such that mitigation as defined in Public Resources Code Section 2693(c) would be required.

1 .5 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
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Source: Soil Zones - Earth Mechanics Inc., 2006; Liquefaction - CDMG, 1999.

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**Figure 3.5-4**
**Soil Zones and Potential Liquefaction Areas**
**City Dock No. 1 Marine Research Center Project**

Moffatt and Nichol (2007) developed the tsunami model for the Los Angeles/Long Beach Port Complex that incorporates consideration of the localized artificial fill configurations, bathymetric features (water depth and topography of the harbor bottom), and the interaction of the diffraction (bending of waves around obstacles), reflection (change in direction due to interference), and refraction (change in direction due to speed) of tsunami wave propagation in the predictions of tsunami wave heights. The Los Angeles/Long Beach Port Complex model uses a methodology similar to the above studies to generate a tsunami wave from several different potential sources, including local earthquakes, remote earthquakes, and local submarine landslides.

The model specifically examined seven different earthquake- and landslide-generated tsunami scenarios and considered local landfill configurations, bathymetric features, and the interaction of tsunami wave propagation to predict tsunami wave heights that could affect the harbor (Moffatt and Nichol 2007). The model predicts tsunami wave heights with respect to MSL rather than MLLW, which is a reasonable, average condition under which a tsunami might occur (Moffatt and Nichol 2007).

The tsunami study identified the lowest deck elevations throughout the Port using various sources of data. It is assumed that these elevations can be used as proxies for certain areas of the proposed Project that are not specifically identified in the tsunami report (i.e., the Outer Harbor area). The lowest deck elevations identified in the tsunami study in the proposed project area included Berths 56–60 along the East Channel with adjacent lowest deck elevations as low as 11.19 feet above MSL, and Berths 70–71 along the Main Channel with adjacent lowest deck elevations as low as 12.17 feet above MSL.

Based on the model, four out of the seven scenarios could result in tsunami-induced flooding in the proposed project area. Table 3.5-3 below shows the four scenarios that could lead to tsunami-induced flooding in the proposed project area. See Figures 3.5-5 through 3.5-8 for a depiction of the modeling results and the water level, in meters, above mean sea level.

**Table 3.5-3.** Modeled Conditions that Could Result in Tsunami-Induced Flooding

| *Model Scenario* | *Description* | *Minimum Water Levels (meters above MSL) in the Proposed Project Area* | *Maximum Water Levels (meters above MSL) in the Proposed Project Area* |
|---|---|---|---|
| Catalina Fault (seven-segment scenario) | Tectonic tsunami source generated by a magnitude 7.6 earthquake located on the Catalina Fault, line segment 7 | 0.2 | 2.0 |
| Catalina Fault (four-segment scenario) | Tectonic tsunami source generated by a magnitude 7.6 earthquake on the Catalina Fault, line segment 4 | 0.2 | 1.6 |
| Palos Verdes Landslide I | Landslide tsunami sources generated by a submerged ocean slope failure | 0.0 | 2.2 |

| *Model Scenario* | *Description* | *Minimum Water Levels (meters above MSL) in the Proposed Project Area* | *Maximum Water Levels (meters above MSL) in the Proposed Project Area* |
|---|---|---|---|
| Palos Verdes Landslide II | Landslide tsunami sources generated by a submerged ocean slope failure | 0.5 | 7.0 |
| Source: Moffatt and Nichol 2007 | | | |

Based on these model results, there are certain areas of the proposed Project that not only could be exposed to tsunami-induced flooding but could also be exposed to overtopping of the existing deck elevation. Overtopping of the existing deck elevation is determined by identifying the maximum wave height above the MSL predicted by the model for the model locations (see Figures 3.5-5 through 3.5-8). If the maximum wave height above the MSL predicted by the model is greater than the adjacent lowest deck elevation, overtopping would occur at this location as predicted by the model. This provides a conservative estimate as to the locations within the proposed project area that would experience overtopping in the event of a tsunami generated under the conditions modeled, as indicated in Table 3.5-4 below. The modeled Palos Verdes Landslide II conditions clearly pose the most risk of overtopping in the proposed project area.

**Table 3.5-4.** Proposed Project Area Locations that Would Experience Overtopping by Tsunami-Induced Waves

| *Model Locations* | *Adjacent Lowest Deck Elevation*[a] | *Catalina Fault (seven- segment scenario)* | *Catalina Fault (four-segment scenario)* | *Palos Verdes Landslide I* | *Palos Verdes Landslide II* |
|---|---|---|---|---|---|
| East Channel | 11.19 | 2.0 | 1.2 | 2.0 | **3.5**[a] |
| Main Channel | 12.17 | 1.2 | 1.0 | 1.0 | 3.5 |

[a] **Bold** text indicates areas that would experience overtopping

Source: Moffatt and Nichol 2007

## Seiches

Seiches are seismically induced water waves that surge back and forth in an enclosed basin 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 at the proposed project site. Modern shoreline protection techniques are designed to resist seiche damage. Any significant wave front could cause damage to seawalls and docks; however, modern shoreline protection techniques are designed to resist seiche damage. The Los Angeles/Long Beach Port Complex model considered impacts from both tsunamis and seiches. In each case, impacts from a tsunami were equal to or more severe than those from a seiche.

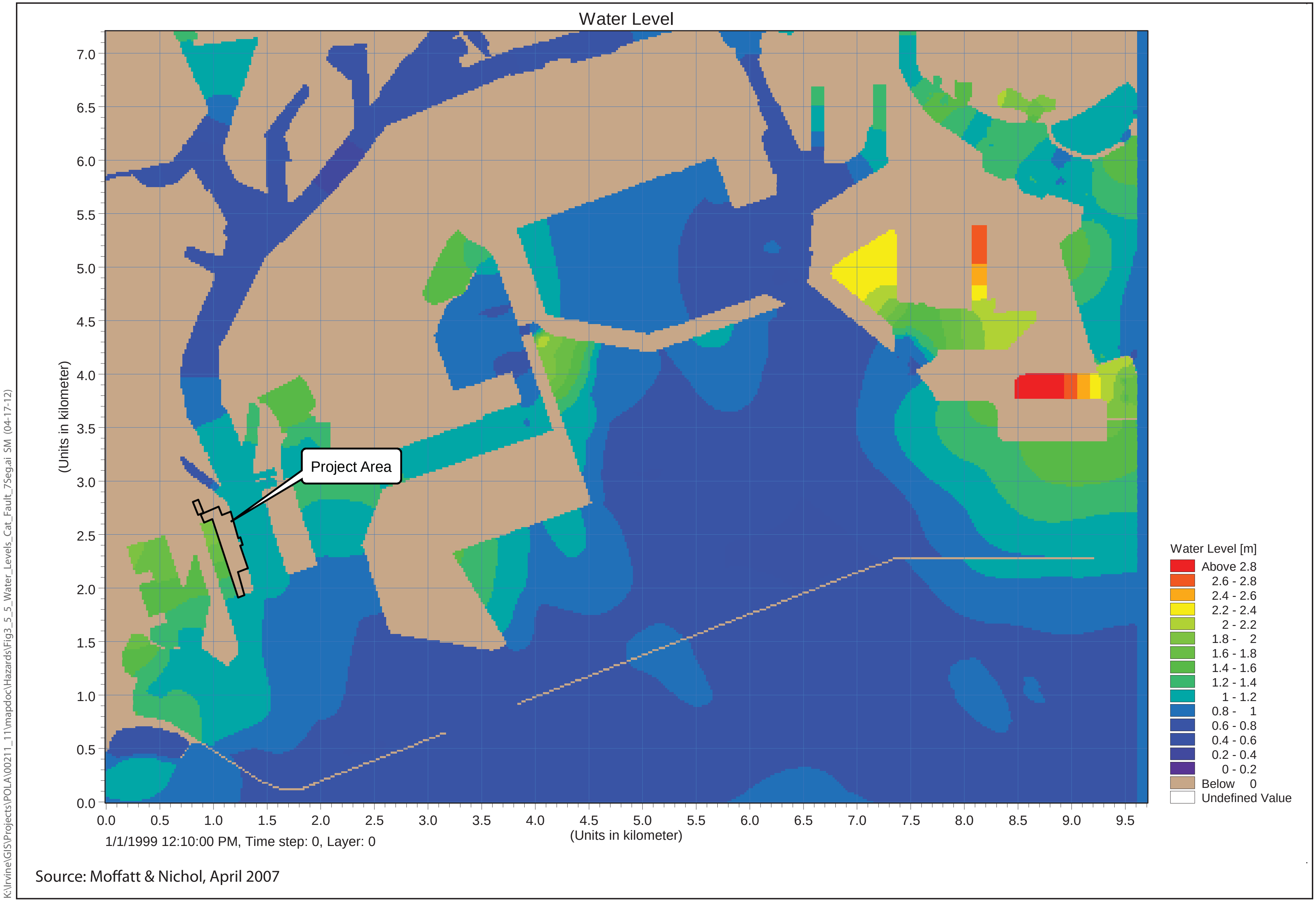


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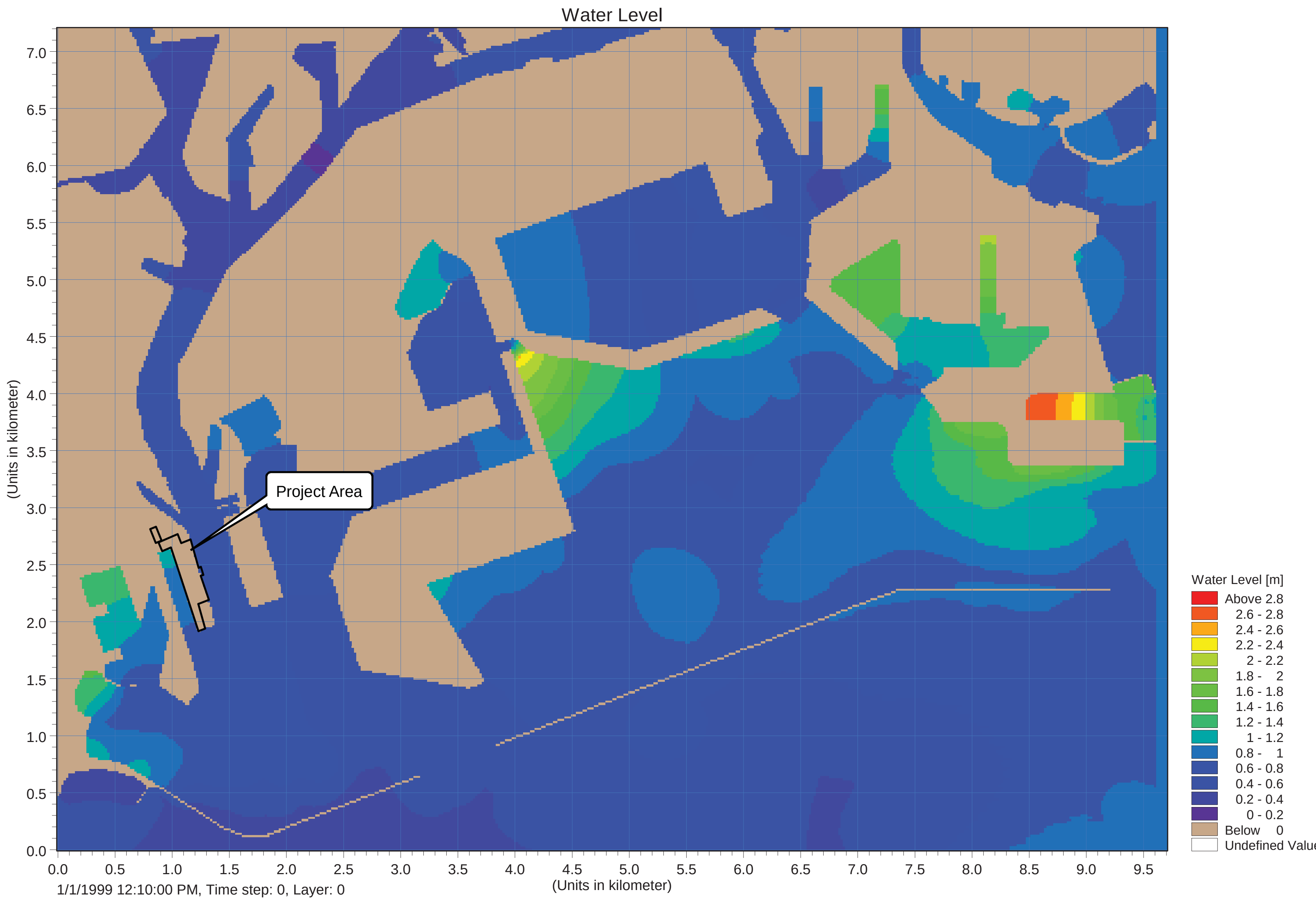
**Figure 3.5-5**
**Maximum Water Levels for the Catalina Fault - 7 Segments Scenario**
**City Dock No. 1 Marine Research Center Project**




Source: Moffatt & Nichol April 2007

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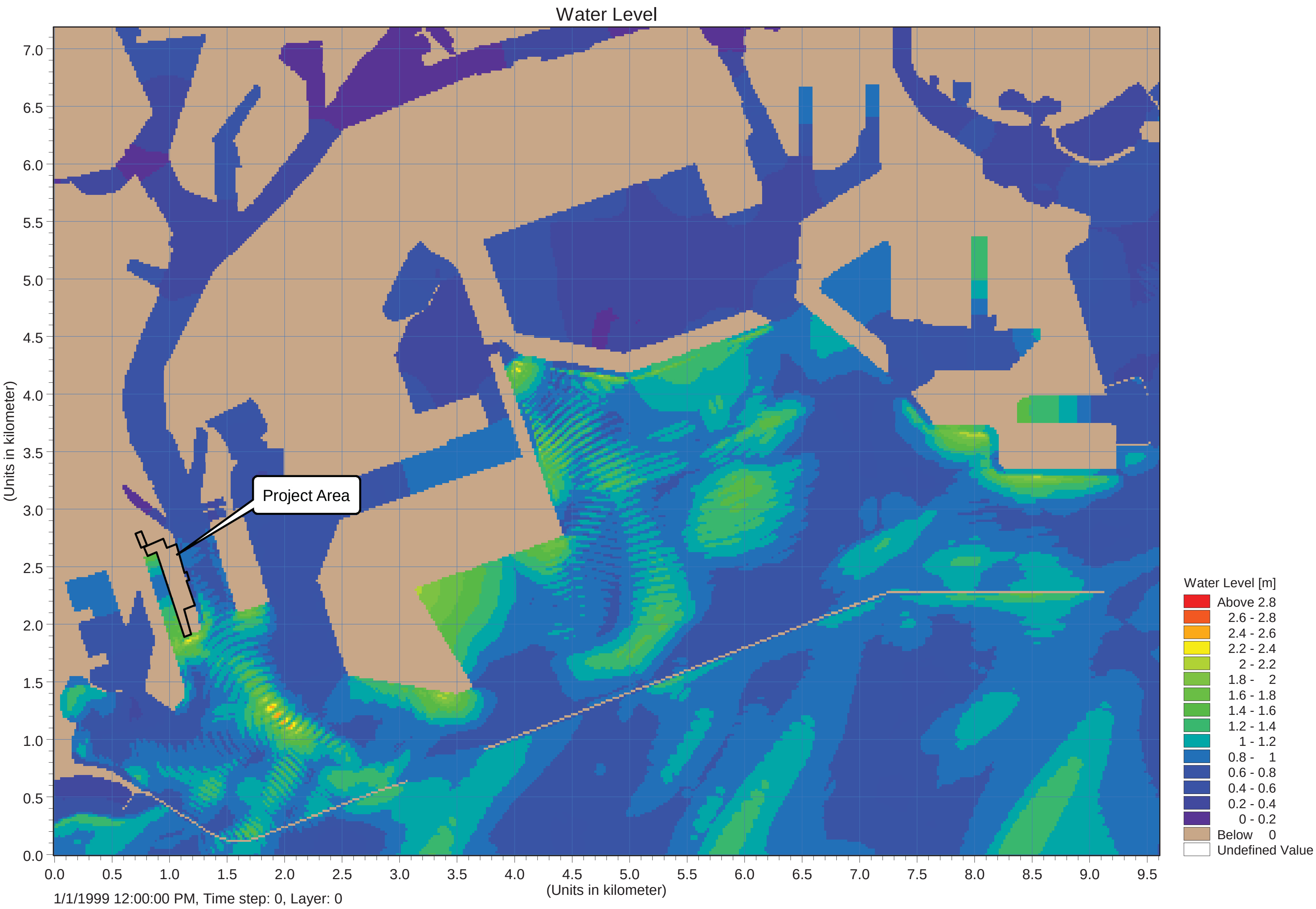
ICF INTERNATIONAL

**Figure 3.5-6**
**Maximum Water Levels for the Catalina Fault - 4 Segments Scenario**
**City Dock No. 1 Marine Research Center Project**




Source: Moffatt & Nichol April 2007

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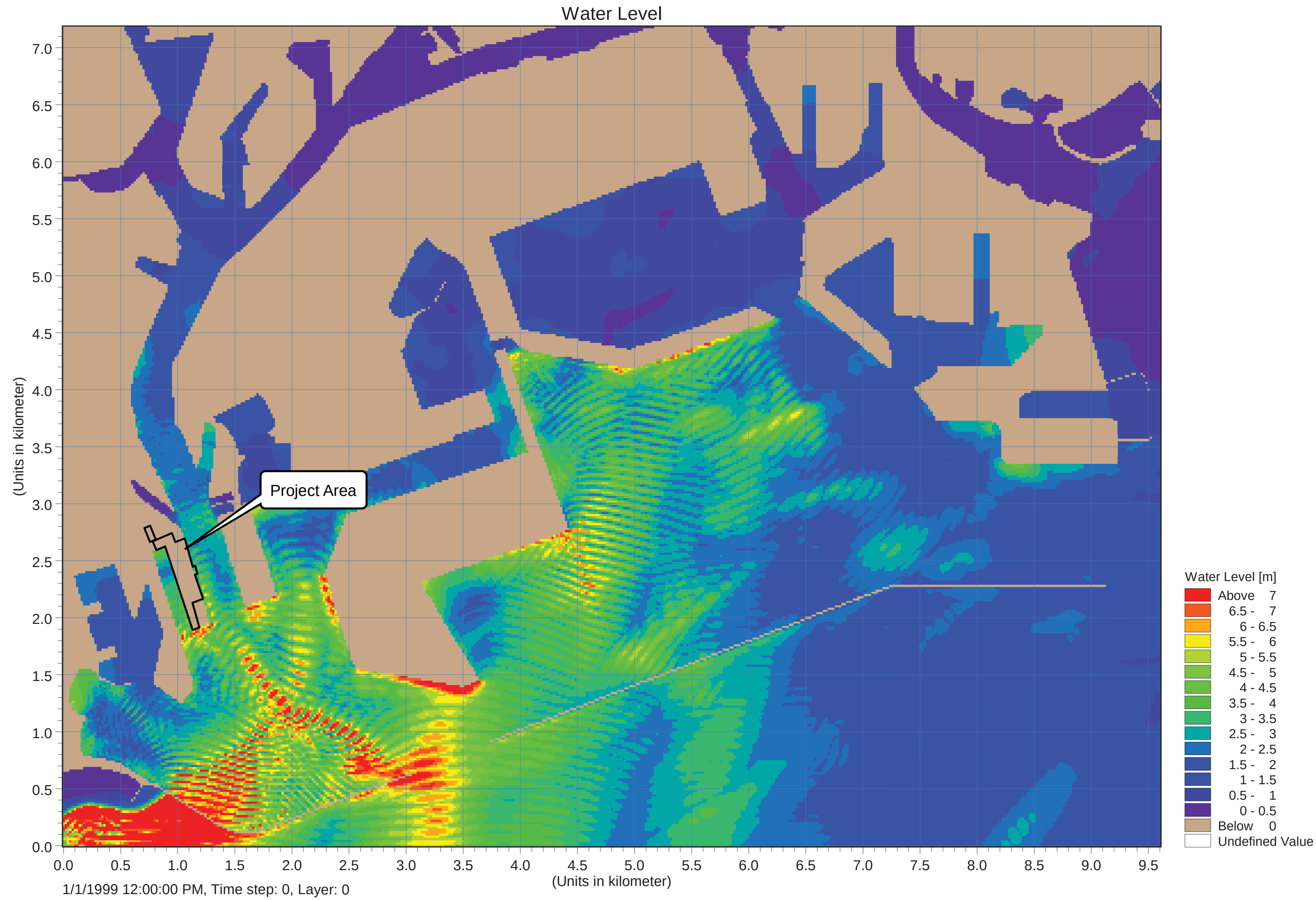
ICF INTERNATIONAL

**Figure 3.5-7**
**Maximum Water Levels for the Palos Verdes Landslide I Scenario**
**City Dock No. 1 Marine Research Center Project**




Source: Moffatt & Nichol April 2007

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ICF INTERNATIONAL

**Figure 3.5-8**
**Maximum Water Levels for the Palos Verdes Landslide II Scenario**
**City Dock No. 1 Marine Research Center Project**

#### 3.5.2.1.2 Mineral Resources

The proposed project site is located to the southwest, and outside, of the approximately 11-mile-long and 3-mile-wide Wilmington Oil Field, which covers approximately 13,500 acres. The southwesterly edge of the field crosses the Los Angeles Harbor to the north of the Vincent Thomas Bridge approximately 1.8 miles northeast of the proposed project site. From January 1998 through October 2002, the field as a whole produced 84.4 million barrels (bbl) of oil, making it the 6$^{th}$ largest producing oil field in the state (California Department of Conservation 2002). The proposed project site is not within an active oil field and no oil production or exploration occurs within the generally vicinity; therefore, this potential resource is not discussed further.

The proposed project site is located primarily on dredged fill material overlying Holocene-age beach and/or shallow water marine sediments. According to the California Geological Survey (1987), the proposed project site is located in a Mineral Resource Zone (MRZ) area classified as "MRZ-1," which is defined as an area where adequate information indicates that no significant mineral deposits (i.e., aggregate deposits) are present or where it is judged that little likelihood exists for their presence; therefore, mineral resources are not discussed further in this section.

## 3.5.3 Applicable Regulations

### 3.5.3.1 Federal

#### 3.5.3.1.1 Occupational Safety and Health Act of 1970: Part 1926 Safety and Health Regulations for Construction

Congress passed the Occupational and Safety Health Act to ensure worker and workplace safety. Their goal was to make sure employers provide their workers a place of employment free from recognized hazards to safety and health, such as exposure to toxic chemicals, excessive noise levels, mechanical dangers, heat or cold stress, or unsanitary conditions.

In order to establish standards for workplace health and safety, the Act also created the National Institute for Occupational Safety and Health (NIOSH) as the research institution for the Occupational Safety and Health Administration (OSHA). OSHA is a division of the U.S. Department of Labor that oversees the administration of the Act and enforces standards in all 50 states.

Part 1926 provides regulations to ensure the safety of construction workers. Subparts to Part 1926 include:

- Subpart E: Personal Protective and Life Saving Equipment
- Subpart L: Scaffolds
- Subpart M: Fall Protection

- Subpart N: Cranes, Derricks, Hoists, Elevators, and Conveyors
- Subpart P: Excavations
- Subpart Q: Concrete and Masonry Construction
- Subpart R: Steel Erection
- Subpart T: Demolition
- Subpart U: Blasting and the Use of Explosives

## 3.5.3.2 State

### 3.5.3.2.1 California Building Code

The State of California provides minimum standards for building design through the California Building Code (CBC). The CBC is based on the International Building Code (formerly known as the Uniform Building Code) established by the International Code Council (formerly known as the International Council of Building Officials), which is used widely throughout the United States (generally adopted on a state-by-state or agency-by-agency basis), and has been modified for conditions within California. In 2008, a revised version of the CBC took effect. In accordance with the CBC, a grading permit is required if more than 50 cubic yards of soil is moved during implementation of a project. Chapter 16 of the CBC contains definitions of seismic sources and the procedure used to calculate seismic forces on structures.

Building codes provide minimum standards regulating a number of aspects of construction that are relevant to geology and geologic hazards. These include excavation, grading, and fill placement; foundations; mitigation of soil conditions such as expansive soils; and seismic design standards for various types of structures.

### 3.5.3.2.2 Alquist-Priolo Act

California's Alquist-Priolo Act (PRC 2621 et seq.), originally enacted in 1972 as the Alquist-Priolo Special Studies Zones Act and renamed in 1994, is intended to reduce the risk to life and property from surface fault rupture during earthquakes. The Alquist-Priolo Act prohibits the location of most types of structures intended for human occupancy across the traces of active faults and strictly regulates construction in the corridors along active faults. It also defines criteria for identifying active faults, giving legal weight to terms such as "active," and establishes a process for reviewing building proposals in and adjacent to active faults.

Under the Alquist-Priolo Act, faults are zoned, and construction along or across them is strictly regulated if they are "sufficiently active" and "well-defined." A fault is considered sufficiently active if one or more of its segments or strands shows evidence of surface displacement during Holocene time (defined for the purposes of the act as within the last 11,000 years). A fault is considered well-defined if its trace can be clearly identified by a trained geologist at the ground surface or in the shallow subsurface, using standard professional techniques, criteria, and judgment.

### 3.5.3.3 Local

#### 3.5.3.3.1 City of Los Angeles

Geologic resources and hazards in the proposed project vicinity are governed primarily by the City of Los Angeles. The Conservation and Safety Elements of the City of Los Angeles General Plan contain policies for the protection of geologic features and avoidance of geologic hazards (City of Los Angeles 1996). Local grading ordinances establish detailed procedures for excavation and earthwork required during construction. In addition, the City of Los Angeles Building Code establishes requirements for construction of building structures (City of Los Angeles 2011). LAHD uses the 2010 California Building Code (CBC) as a basis for seismic design for land-based structures.

LAHD, in conjunction with the City of Los Angeles, LAFD, Los Angeles Police Department (LAPD), Port Police, and USCG, is responsible for managing any emergency related to Port operations, depending on the severity of the emergency.

The City of Los Angeles Emergency Preparedness Department (EPD) provides citywide emergency leadership, continuity, and direction to enable the City and all of its various departments and divisions to respond to, recover from, and mitigate the impact of natural, human-made, or technological disasters upon its people or property. The EPD has prepared a City of Los Angeles Emergency Operations Organization Manual that describes the organization, responsibilities, and priorities of all City departments and local agencies in case of an emergency (EPD 2006). The manual is maintained by EPD and is organized by type of emergency as well as by the City departments that are responsible for responding to certain emergencies. The manual includes the following sections applicable to the Port area:

- LAHD Plan,
- Hazardous Materials Annex, and
- Tsunami Response Plan Annex.

Generally, these various plans established the following emergency operational priorities for the Port:

- provide Port security,
- evacuate vessels for the safety of crew members,
- evacuate Port facilities and the Port area,
- regulate the movement and anchorage of vessels,
- establish liaison with other City/government agencies,
- procure and maintain emergency supplies and equipment,

- establish damage assessment and prioritization procedures,
- identify shelter facilities, and
- provide employee emergency preparedness training.

Specifically, the LAHD Plan of the City of Los Angeles Emergency Operations Organization Manual identifies very general initial policies and procedures covering LAHD's response in the event of any emergency.

The Hazardous Materials Annex contains information regarding the chain of command and the general organization of any response to a hazardous material release anywhere in the City, including the Port area (EPD 1993). It includes an emergency checklist for LAHD to follow should a hazardous materials release occur within the Port area. The checklist identifies specific pre-event, response, and recovery action items and identifies the respective LAHD divisions (i.e., Port Police) that are responsible for carrying out the action items.

The Tsunami Response Plan Annex identifies the Port area as a Tsunami Inundation Zone and outlines policies and procedures of nine different City departments (including LAHD, LAPD, LAFD, and EMD) in the event of a tsunami (EPD 2008). The Tsunami Response Plan identifies evacuation routes for the San Pedro area and the harbor area and specifies evacuation locations to which evacuees should retreat. The plan identifies that the mission of LAHD with respect to a tsunami is to provide employees, tenants, and the public with a safe, well-planned, and organized method of evacuating the Port district. It outlines several actions that the Port Police are responsible for, including following the established evacuation checklist, evacuating the affected Tsunami Inundation Zone, and activating notification procedures. The divisional organization and basic functions that would support the Tsunami Response Plan for the Port area are consistent with LAHD's emergency plan and procedures.

The City and LAHD have adopted the Standardized Emergency Management System (SEMS) to manage responses to multi-agency and multi-jurisdiction emergencies and facilitate communications and coordination among all levels of the system and among all responding agencies. Additionally, the City currently uses a new emergency management process that incorporates Homeland Security's National Incident Management System (NIMS) and Incident Command System (ICS) and the application of standardized procedures and preparedness measures (Malin pers. comm. 2011).

In addition to the emergency response plans EPD maintains, LAHD maintains emergency response and evacuation plans. The Homeland Security Division of LAHD is responsible for maintaining and implementing LAHD's Emergency Procedures Plan. This plan was last revised in 2012. LAHD's Emergency Procedures Plan references LAHD's evacuation plan. The evacuation plan is maintained and implemented by the Port Police and in consultation with the Homeland Security Division and USCG. LAHD's evacuation plan was last updated in 2005.

Finally, each tenant at the Port is responsible for maintaining its own emergency response plan (Malin pers. comm. 2011). Tenants must comply with emergency and security regulations enforced by LAFD, Port Police, Homeland Security Division, and USCG.

# 3.5.4 Impact Analysis

## 3.5.4.1 Methodology

Geological impacts have been evaluated in terms of both impacts of the proposed Project on the local geologic environment, and impacts of existing geohazards on components of the proposed Project that may result in substantial damage to structures or infrastructure or expose people to substantial risk of injury. Impacts would be considered significant if the proposed Project meets any of the significance criteria listed in Section 3.5.4.2 below.

The environmental setting as described in Section 3.5.2 above was used as the baseline physical conditions by which significant potential impacts were evaluated. Some of the geologic maps and literature used to prepare the environmental setting are 10 to 20 years old. However, the geologic conditions did not change significantly over this time period, and therefore the use of these materials is considered appropriate for this study.

The IS/NOP determined that the proposed Project would have less-than-significant impacts on the following geology and soils issues; therefore, they will not be discussed in the geology impact analysis below:

- have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems in areas where sewers are not available for the disposal of wastewater;
- result in the permanent loss of availability of a known mineral resource of regional, state, or local significance that would be of future value to the region and the residents of the state; or
- result in the loss of availability of a locally important mineral resource recovery site delineated on a local general plan, specific plan, or other land use plan.

The IS/NOP determined that the Los Angeles Department of Public Works Bureau of Sanitation provides sewer service to all areas within its jurisdiction, including the proposed project site. The proposed Project would be connected to this system, and sewage would be sent to the Terminal Island Treatment Facility. Alternatively, ocean water used for aquaculture and research purposes may be treated either by (1) sending it to the Terminal Island Treatment Facility, (2) using a flow-through system that would treat on site and allow pass-through back into the bay, or (3) a combination of each. More details on both options are provided in Section 3.13, “Water Quality, Sediments, and Oceanography.” There would be no use of septic tanks or other soil-based alternative wastewater disposal systems and hence no impact related to soils incapable of adequately supporting a septic or alternative wastewater system. Therefore, this criterion will not be discussed in the geology impact analysis below.

The proposed project area is not within a significant aggregate resource zone; the proposed project site is in a mineral resource zone area classified as MRZ-1, which is defined as an area where adequate information indicates that no significant mineral deposits are present, or where it is judged that little likelihood exists for their presence (California Department of Conservation, Division of Mines and Geology 1987). The proposed project site does not contain nor is it in close proximity to an oil, gas, or geothermal well. In addition, the proposed project site is not known to contain mineral resources that would be of value to the region or state. No quarrying operations are established in the vicinity of the proposed project site, and the nearest oil field and drilling areas include the Torrance Oil Field, located north of US 1, and the Wilmington Oil Field, located in the northern portion of the Port. The proposed project site is in an area that contains several recreational facilities and in which industrial operations would be limited or relocated, therefore reducing the potential for mining or drilling in the area. Consequently, no impacts to mineral resources would occur.

The assessment of impacts is based on regulatory controls and on the assumptions that the proposed Project would include the following standards and engineering requirements:

- LAHD or authorized developers within the proposed project area will design and construct upland improvements in accordance with Los Angeles Building Code, Sections 91.000 through 91.7016 of the Los Angeles Municipal Code, to minimize impacts associated with seismically induced geohazards. These sections regulate construction in upland areas of the Port. Because there are no upland elements associated with the proposed Project, these building codes and requirements do not apply.
- LAHD will design and construct new wharf and related improvements in accordance with LAHD standards, to minimize impacts associated with seismically induced geologic, soils, and seismic hazards. Such construction will include, but not be limited to, completion of site-specific geotechnical investigations regarding construction and foundation engineering. Measures pertaining to temporary construction conditions, such as protecting adjacent structures, will be incorporated into the design. A licensed geologist or engineer will monitor construction to ensure that all building is consistent with the proposed project design.

## 3.5.4.2 Thresholds of Significance

The following significance criteria are based on the *L.A. CEQA Thresholds Guide* (City of Los Angeles 2006) and are the basis for determining the significance of impacts associated with geology and soils resulting from development of the proposed Project.

Geologic hazard impacts are considered significant if the proposed Project causes or accelerates hazards that would result in substantial damage to structures or infrastructure, or exposes people to substantial risk of injury. Because the region is considered to be geologically active, most projects are exposed to some risk from geologic hazards, such as earthquakes. Geologic impacts are, therefore, considered significant if the proposed Project would result in any of the following:

**GEO-1:** Substantial damage to structures or infrastructure, or expose people to substantial risk of injury from fault rupture, seismic ground shaking, liquefaction, or other seismically induced ground failure.

**GEO-2:** Substantial damage to structures or infrastructure, or expose people to substantial risk of injury from tsunamis or seiches.

**GEO-3:** Substantial damage to structures or infrastructure, or expose people to substantial risk of injury from land subsidence/settlement.

**GEO-4:** Substantial damage to structures or infrastructure, or expose people to substantial risk of injury from expansive soils.

**GEO-5:** Substantial damage to structures or infrastructure, or expose people to substantial risk of injury from landslides or mudflows.

**GEO-6:** Substantial damage to structures or infrastructure, or expose people to substantial risk of injury from unstable soil conditions from excavation, grading, or fill.

**GEO-7:** Destroy, permanently cover, or materially and adversely modify one or more distinct and prominent geologic or topographic features. Such features may include, but not be limited to, hilltops, ridges, hillslopes, canyons, ravines, rock outcrops, water bodies, streambeds, and wetlands.

## 3.5.4.3 Impacts and Mitigation

### 3.5.4.3.1 Construction Impacts

#### Impact GEO-1a: Construction of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from fault rupture, seismic ground shaking, liquefaction, or other seismically induced ground failure.

The proposed project area lies in the vicinity of the Palos Verdes Fault Zone. Current data suggest that segments of the fault may pass within approximately 0.7 mile east of the proposed project site (Earth Mechanics, Inc. 2006; Figure 3.5-3), but no strands of the fault pass beneath the proposed project site. Strong-to-very strong ground shaking, severe ground settlement, and liquefaction could occur at the proposed project site because of the proximity of the fault and the presence of low relative density and water-saturated hydraulic fill and marine deposits. Projects in construction phases are especially susceptible to earthquake damage due to temporary conditions, such as temporary slopes and unfinished structures, which are typically not in a condition to withstand intense ground shaking. Strong ground shaking would potentially cause damage to unfinished structures resulting in injury to construction workers. There would be a temporary influx of construction crews to the proposed project site, which would slightly increase the exposure of workers to seismic hazards relating to the baseline condition.

With the exception of ground rupture, there would be similar seismic impacts on other regional faults. Earthquake-related hazards, such as fault rupture, severe ground settlement, liquefaction, and seismic ground shaking cannot be avoided in the Los Angeles region and in particular in the harbor area where the Palos Verdes Fault and low density or liquefaction-prone soils are present.

As described in Chapter 2, "Project Description," wharf improvements would be implemented during construction of the proposed Project. Currently, there are two options, both of which would use "super piles." Either option, once implemented, would stabilize the slope and repair the wharf structure over which the Berths 57 and 58–60 transit sheds are built. Furthermore, the transit sheds would be upgraded to current CBC and UBC standards. These upgrades would greatly enhance the existing structures' ability to withstand strong ground shaking, liquefaction, and other seismically induced ground failure. All new construction would also comply with CBC and City building and safety codes.

Construction would occur in accordance with established CBC and City Building Code, and worker safety would be regulated by the OSHA pursuant to the Occupational Safety and Health Act of 1970 (OSH Act) contained in Title 29 of the Code of Federal Regulations (29 CFR). Part 1926 specifically outlines regulations for construction. Under the OSH Act, employers are responsible for providing a safe and healthful workplace. OSHA's mission is to assure safe and healthful workplaces by setting and enforcing standards, and by providing training, outreach, education, and assistance. Additionally, the Port as an agency within the City of Los Angeles has several emergency plans in place that may be implemented in the event of an emergency in order to respond and evacuate Port facilities. Compliance with all applicable laws and regulations would minimize exposure to risk from seismic hazards, and impacts would be less than significant.

#### Mitigation Measure

No mitigation is required.

#### Residual Impacts

Impacts would be less than significant.

### Impact GEO-2a: Construction of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk involving tsunamis or seiches.

Because of the historic occurrence of earthquakes, tsunamis, and seiches along the Pacific Rim, placement of any development on or near the shore in southern California, including at the proposed project site, would always involve some measure of risk of impacts from a tsunami or seiche. Although relatively rare, should a large tsunami or seiche occur, it would be expected to cause some amount of damage and possibly injuries to most on- or near-shore locations. As a result, this is considered by LAHD as the average, or normal condition for most on- and near-shore locations in southern California.

Therefore, a tsunami- or seiche-related impact would be significant if it would exceed this normal condition and cause substantial damage and/or substantial injuries. Under a theoretical maximum worst-case scenario, construction of the proposed Project would expose people or property to substantial damage or injuries in the event of a tsunami or seiche.

Because tsunamis and seiches are derived from wave action, the risk of damage or injuries from these events at any particular location is lessened if the location is high enough above sea level, far enough inland, or protected by anthropogenic structures such as dikes or concrete walls. The height of a given site above sea level is either the result of an artificial structure (e.g., a dock or wall), topography (e.g., a hill or slope), or both; and a key variable related to the height of a site location relative to sea level is the behavior of tides. During high tide, for instance, the distance between the site and sea level is less. During low tide, the distance is greater. How high a site must be located above sea level to avoid substantial wave action during a tsunami or seiche depends upon the height of the tide at the time of the event and the height of the potential tsunami or seiche wave.

The harbor is subject to diurnal tides, meaning two high tides and two low tides during a 24-hour day. The average of the lowest water level during low tide periods each day is typically set as a benchmark of 0 feet and is defined as MLLW. For purposes of this discussion, all proposed project structures and land surfaces are expressed as height above (or below) MLLW. The MSL in the harbor is +2.82 feet above MLLW (NOAA 2008). This height reflects the arithmetic mean of hourly heights observed over the National Tidal Datum Epoch (19 years) and, therefore, reflects the mean of both high and low tides in the harbor. The recently developed Los Angeles/Long Beach Port Complex probabilistic model described in Section 3.5.2.1.1 above predicts tsunami wave heights with respect to MSL, rather than MLLW and, therefore, can be considered a reasonable average condition under which a tsunami might occur (Moffatt and Nichol 2007).

The Los Angeles/Long Beach Port Complex study identified the lowest deck elevations throughout the Port using various sources of data. The deck elevations that are the lowest within the proposed project area are those surrounding the West

Channel and in the Cabrillo Marina. These elevations are based on an aerial survey performed in February 1999 and information from the LAHD. The lowest deck elevations within the proposed project site adjacent to the East Channel and Main Channel are approximately 11.2 and 12.2 feet above MSL, respectively (Moffatt and Nichol 2007).

The Los Angeles/Long Beach Port Complex model predicts maximum tsunami wave heights in the Port area of approximately 5.2 to 6.6 feet above MSL for the earthquake scenario and approximately 7.2 to 23.0 feet above MSL for the landslide scenario. The highest anticipated water levels from these scenarios would occur in the Outer Harbor area. For the Palos Verdes Landslide II scenario (Moffat and Nichol 2007), their Figure 4-6 indicates a 23-foot wave height at the south end of the proposed project site. Based on the lowest deck elevations presented above, tsunami-induced flooding would not occur at the proposed project site under most of the earthquake and landslide scenarios. Travel times vary for the Catalina fault scenarios (12 to 29 minutes) and the landslide scenarios (6 to 14 minutes).

Based on studies cited above, as a part of their Marine Oil Terminal Engineering and Maintenance Standards (MOTEMS) (SLC 2011) tsunami run-up projections for the Port are 8 and 15 feet above MSL, at 100- and 500-year intervals, respectively. The 500-year interval tsunami would overtop the existing lowest elevations at the proposed project site.

All of the studies previously cited indicate that modeled worst-case tsunami scenarios for earthquake and landslide scenarios have long recurrence intervals. For the initiating events in offshore southern California, this is likely at least 5,000 to 10,000 years. Additionally, there is no certainty that any of these earthquake or landslide events would result in a tsunami, since only about 10% of earthquakes worldwide result in a tsunami.

### Impact Determination

Because construction at portions of the proposed project site would be at lower elevations than predicted tsunami wave heights, there is a substantial risk of coastal flooding due to tsunamis and seiches. Designing new facilities based on existing building codes may not prevent substantial damage to structures from coastal flooding. In addition, projects in construction phases are especially susceptible to damage due to temporary conditions, such as unfinished structures, which are typically not in a condition to withstand coastal flooding. Impacts from tsunamis and seiches can occur at any time along the entire California coastline and would not be increased by construction of the proposed Project.

Emergency planning and coordination between the Port contractors and LAHD would contribute to reducing onsite injuries during a tsunami. Port engineers and LAHD police will work with contractors to develop earthquake and tsunami response training and procedures based on the Port's tsunami plan to ensure that construction and operations personnel will be prepared to act in the event of a large seismic event. These procedures will include immediate evacuation requirements in the event that a large seismic event is felt at the proposed project site. Compliance with all applicable laws and regulations would minimize exposure to risk from tsunami and seiche hazards, and impacts would be less than significant.

#### Mitigation Measure

No mitigation is required.

#### Residual Impacts

Impacts would be less than significant.

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

Subsidence in the vicinity of the proposed Project could occur in the absence of proper engineering, and proposed structures would potentially be cracked and warped as a result of saturated and/or unconsolidated/compressible sediments. During proposed project design, the geotechnical engineer would evaluate the settlement potential in areas where structures are proposed and provide measures to ensure acceptable (small) settlements would occur.

The settlement potential of existing onshore soils would be evaluated through a site-specific geotechnical investigation prior to final structural designs, which includes subsurface soil sampling, laboratory analysis of samples collected to determine soil compressibility, and an evaluation of the laboratory testing results by a geotechnical engineer. Recommendations of the engineer would be incorporated into the design specifications for the proposed Project, consistent with City design guidelines, including Sections 91.000 through 91.7016 of the Los Angeles Municipal Code, in conjunction with criteria established by LAHD. Sections 91.000 through 91.7016 regulate construction in upland areas of the Port. These building codes and criteria provide requirements for construction, grading, excavations, use of fill, and foundation work, including type of materials, design, procedures, etc. These codes are intended to limit the probability of occurrence and the severity of consequences from geological hazards. Recommendations for soils subject to settlement typically include over excavation and recompaction of compressible soils, which would allow for construction of a conventional slab-on-grade; or alternatively, installation of concrete or steel. Such geotechnical engineering would substantially reduce the potential for soil settlement during and after construction, and would allow for construction that would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury.

#### Impact Determination

Settlement impacts at the proposed project site, particularly during construction, would be less than significant, because the proposed Project would be designed and constructed in compliance with the recommendations of the geotechnical engineer, consistent with Sections 91.000 through 91.7016 of the Los Angeles Municipal Code and in conjunction with criteria established by LAHD. Therefore, impacts would be less than significant.

#### Mitigation Measures

No mitigation is required.

#### Residual Impacts

Impacts would be less than significant.

### Impact GEO-4a: Construction of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from expansive soils.

Expansive soil may be present in the proposed project area and in excavated or imported soils used for proposed project grading. Expansive soils beneath the foundations, pavement, or behind retaining structures would potentially result in cracking and distress of these structures. However, during the design phase, the geotechnical engineer would evaluate the expansion potential associated with onsite soils through a site-specific geotechnical investigation, which would include subsurface soil sampling, laboratory analysis of samples collected to determine soil expansion potential, and an evaluation of laboratory testing results. The engineer's recommendations would be incorporated into the design specifications for the proposed Project, consistent with City design guidelines, including Sections 91.000 through 91.7016 of the Los Angeles Municipal Code, in conjunction with criteria established by LAHD. Recommendations for soils subject to expansion typically include over-excavation and replacement of expansive soils with sandy, non-expansive soils, which would allow for construction of a conventional slab-on-grade; construction of post-tensioned concrete slabs, which can accommodate movement of underlying expansive soils; or, alternatively, installation of concrete or steel foundation piles through the expansion-prone soils, to a depth of non-expansive soils. Therefore, required geotechnical site engineering would substantially reduce the potential for soil expansion and damage to overlying structures.

#### Impact Determination

Expansive soil impacts at the proposed project site would be less than significant because the proposed Project would be designed and constructed in compliance with the recommendations of the geotechnical engineer, consistent with implementation of Sections 91.000 through 91.7016 of the Los Angeles Municipal Code, and in conjunction with criteria established by LAHD. Therefore, the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury, and the impact would be less than significant.

#### Mitigation Measures

No mitigation is required.

#### Residual Impacts

Impacts would be less than significant.

### Impact GEO-5a: Construction of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from landslides or mudslides.

Numerous ancient and recent landslides have occurred within the southerly portion of the Palos Verdes Hills, which includes the large Portuguese Bend landslide complex, several miles to the southwest of the proposed project site. The proposed project site is offshore, with a flat surface topography and no significant slopes in nearby inshore areas. The proposed project site and vicinity are not located in an area susceptible to earthquake-induced landslides (CDMG 1998a, 1998b).

A Converse Davis Dixon Associates 1976 geotechnical investigation at Berth 49 south determined that "land slippage" (lateral up to 14 feet and vertical up to 5 feet) occurred due to a landslide that moved on soft, eastward dipping Malaga Mudstone weak bedding planes offshore below the water surface. Such bedding plane conditions may exist at the proposed project site, and a similar bedding plane failure is possible. Therefore, there is a potential risk associated with landslides on site unless proper investigations, designs, and construction implementation/inspection take place. The landslide potential would be evaluated through a site-specific geotechnical investigation prior to final structural designs. Recommendations of the geotechnical engineer would be incorporated into the design specifications for the proposed Project, consistent with City design guidelines, including Sections 91.000 through 91.7016 of the Los Angeles Municipal Code, in conjunction with criteria established by LAHD. Compliance with these requirements would avoid effects from landsliding.

#### Impact Determination

The subsurface bedrock and bathymetry in the vicinity of the proposed project site indicates a potential for landsliding. Appropriate geotechnical engineering would substantially reduce the impacts from potential landsliding, and would allow for construction that would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury. Therefore, impacts would be less than significant.

#### Mitigation Measure

No mitigation is required.

#### Residual Impacts

Impacts would be less than significant.

### Impact GEO-6a: Construction of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from unstable soil conditions from excavation, grading, or fill.

Natural alluvial and marine deposits, as well as anthropogenic artificial fill consisting of dredged deposits or imported soils, would be encountered during excavations for foundations, utility relocation, retaining structures, or other facilities at the proposed project site. Groundwater (seawater) is present at depths approximately equivalent to mean sea level or roughly 10 feet deep. Saturated materials near and below this level would be relatively soft and unstable for engineering purposes, requiring implementation of geotechnical remediation, such as installation of dewatering wells and/or temporary sheet pile shoring, to facilitate excavation and worker/equipment access. These methods would lower the water level and stabilize excavations, thus reducing the potential for impacts resulting from unstable soils.

A site-specific geotechnical evaluation would be performed during the design phase to provide recommendations for stability of foundations and slopes. Such recommendations would include specification of the material types to be used for fill, compaction specifications, slope inclination, removal of unsuitable material prior to placing fill, and slope armoring with rip-rap/rock to enhance overall stability and work area safety.

Contaminated material, if encountered, would be evaluated by an environmental professional. Handling of contaminated soil, including disposal at an appropriate facility, would be performed under the direction of the environmental professional. Further information regarding the handling and disposal of contaminated materials is provided in Section 3.6, "Groundwater and Soils."

#### Impact Determination

Groundwater (seawater) is present at depths approximately equivalent to mean sea level or roughly 10 feet deep. Saturated materials near and below this level would be relatively soft and unstable for engineering purposes, requiring implementation of geotechnical remediation, such as installation of dewatering wells and/or temporary sheet pile shoring, to facilitate excavation and worker/equipment access. Appropriate geotechnical engineering consistent with existing grading regulations would substantially reduce the impacts from unstable and saturated soil conditions, and would allow for construction that would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury. Therefore, impacts would be less than significant.

**Mitigation Measures**

No mitigation is required.

**Residual Impacts**

Impacts would be less than significant.

### Impact GEO-7a: Construction of the proposed Project would not destroy, permanently cover, or materially and adversely modify one or more distinct and prominent geologic or topographic features. Such features may include, but not be limited to, hilltops, ridges, hillslopes, canyons, ravines, rock outcrops, water bodies, streambeds, and wetlands.

Because the proposed project area is relatively flat and previously disturbed and/or paved, there are no prominent geologic or topographic features. Therefore, proposed project construction would not result in any distinct and prominent geologic or topographic features being destroyed or permanently covered.

**Impact Determination**

Because there are no prominent geologic or topographic features at the proposed project site, no features would be destroyed, covered, moved, or modified. There would be no impacts.

**Mitigation Measures**

No mitigation is required.

**Residual Impacts**

No impacts would occur.

## 3.5.4.3.2 Operational Impacts

### Impact GEO-1b: Operation of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from fault rupture, seismic ground shaking, liquefaction, or other seismically induced ground failure.

With implementation of the proposed Project, there would be an increase in the exposure of people and property to seismic hazards compared to the baseline condition. The proposed project area lies in the vicinity of the Palos Verdes Fault Zone. Based on Earth Mechanics, Inc. (2006, Figure 3.5-3) no strands of the fault pass beneath the proposed project site or near vicinity. Strong-to-very strong ground shaking, severe ground settlement, and liquefaction could occur at the proposed project site during operations because of the proximity of the fault and the presence of low relative density and water-saturated hydraulic fill and marine deposits. With the exception of ground rupture, there would be similar seismic impacts on other regional faults. Earthquake-related hazards, such as fault rupture, severe ground settlement, liquefaction, and seismic ground shaking cannot be avoided in the Los Angeles region and in particular in the harbor area where the Palos Verdes Fault and low density or liquefaction-prone soils are present.

As described in Chapter 2, "Project Description," wharf improvements would be implemented during construction of the proposed Project. Currently, there are two options, both of which would use "super piles." Either option, once implemented, would ensure further damage to the wharf at Berths 57–60 would be eliminated and potential damage to the above structures (transit sheds) would be substantially reduced. Furthermore, the transit sheds would be upgraded to current CBC and UBC standards. These upgrades would greatly enhance the existing structures' ability to withstand strong ground shaking, liquefaction, and other seismically induced ground failure during operation of the proposed Project. The OLE and CLE design criteria provide for levels of structural design that minimize injuries and severe earthquake damage. All new construction would also comply with CBC and City building and safety codes, thereby minimizing impacts to people and structures during operations.

#### Impact Determination

As discussed above under Construction Impacts, seismic activity along the Palos Verdes Fault Zone, or other regional faults, would potentially produce fault rupture, seismic ground shaking, liquefaction, or other seismically induced ground failure. Seismic hazards are common to the Los Angeles region and would not be increased with implementation of the proposed Project. Because the proposed project site is potentially underlain by low density and liquefaction-prone hydraulic fill and marine sediments, and subject to substantial risk of seismic impacts, design and construction would be in accordance with modern construction engineering and safety standards. Additionally, the Port as an agency within the City of Los Angeles has several emergency plans in place that may be implemented in the event of an emergency in order to respond and evacuate Port facilities. Compliance with all applicable laws and regulations would minimize exposure to risk from seismic hazards, and impacts would be less than significant.

#### Mitigation Measures

No mitigation is required.

#### Residual Impacts

Impacts would be less than significant.

### Impact GEO-2b: Operation of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk involving tsunamis or seiches.

See Impact GEO-2a above for a discussion of the probability and anticipated magnitude of a tsunami at the proposed project site. As discussed for Impact GEO-2a, designing new facilities based on existing building codes may not prevent substantial damage to structures from coastal flooding. Impacts that result from seismically induced tsunamis and seiches are typical for the entire California coastline and would not be increased by operation of the proposed Project. However, because portions of the proposed project site are at elevations lower than the predicted tsunami wave heights, there is a substantial risk of coastal flooding in the event of a tsunami and seiche.

For onsite personnel and visitors, the risk of tsunami or seiche is a part of any ocean-shore interface; therefore, people working at or visiting the proposed project site cannot avoid some risk of exposure. Similarly, berth infrastructure would be subject to some risk of exposure. Initial tsunami-induced run-up would potentially cause substantial injury and damage to infrastructure, and the drawdown of water after run-up exerts an opposite force, washing loose/broken debris out to sea. Floating debris brought back on the next onshore flow has been found to cause significant and extensive damage.

Similarly, for vessels, the risk of tsunami or seiches is a part of any ocean-shore interface; therefore, vessels in transit or at berth cannot avoid some risk of exposure. A vessel destined for the proposed project berths would be under its own power and would likely be able to maneuver to avoid damage.

Port engineers have indicated that currents moving over 5 meters per second (m/s) could potentially render a ship out of control (LAHD 2008). Modeling indicates that tsunami-related currents created as a result of a large earthquake on the Santa Catalina Fault or submarine landslide off the coast of the nearby Palos Verdes Peninsula would not create currents in the harbor in excess of 5 m/s. The highest anticipated current speeds of 2 m/s would occur in the vicinity of the entrance to the Main Channel (LAHD 2008). Currents in the vicinity of the Vincent Thomas Bridge (northerly edge of the proposed project area) would be approximately 0.9 m/s (Moffatt and Nichol 2007).

During a tsunami or seiche, a vessel docked at one of the proposed project berths would be subject to the rising and falling of water levels and accompanying currents. Two scenarios could arise. Either the vessel would stay secured to the berth and ride out the tsunami, or its mooring lines would break and the ship would be set adrift. In the first scenario, the energy of a tsunami wave would be transmitted through the vessel and into the wharf. Forces transmitted through the vessel would be transferred to the fendering system of the wharf and then to the wharf structure (LAHD 2008).

The existing wharf fendering systems are designed with the assumption that, under a normal docking scenario, a berthing vessel will contact only one fender. In such scenarios, each fender is designed to absorb the berthing energy of the entire vessel. During a tsunami occurrence, the wave can be assumed to move the vessel against more than one of the existing fenders, so that the vessel would be contacting a minimum of four to five fenders, often simultaneously. In such cases, the force experienced by each fender would be less than the standard docking force for which the system is designed, because more than one fender would absorb the force simultaneously. Therefore, substantial damage is not expected to a vessel or the wharf in the event of a tsunami strike while a vessel is secured at berth (LAHD 2008).

Under the second scenario, a vessel set adrift in the harbor could create more serious situations with increased potential for collisions, including a potential hull breach and possible fuel spill (LAHD 2008).

### Impact Determination

Designing new facilities based on existing building codes may not prevent substantial damage to structures from coastal flooding. Because portions of the proposed project site are at elevations lower than predicted tsunami wave heights, there is a substantial risk of coastal flooding from tsunamis and seiches. Impacts as a result of seismically induced tsunamis and seiches can occur at any time along the entire California coastline and would not be increased by operation of the proposed Project. Raising the elevation of the site or constructing a wall along the perimeter of the site of sufficient height would be the only way to mitigate potential impacts. However, elevating the proposed project site or building a wall around the entire perimeter would be cost-prohibitive and would significantly impact existing infrastructure, requiring extensive modification. Therefore, complete mitigation of the risk of a tsunami is not feasible. Port engineers and LAHD police would work with tenants to develop earthquake and tsunami response training and procedures based on the Port's tsunami plan to ensure that employees and visitors to the site would be prepared to act in the event of a large seismic event. These procedures would include immediate evacuation requirements in the event that a large seismic event is felt at the proposed project site. Compliance with all applicable laws and regulations would minimize exposure to risk from tsunami and seiche hazards, and impacts would be less than significant.

### Mitigation Measure

No mitigation is required.

### Residual Impacts

Impacts would be less than significant.

## Impact GEO-3b: Operation of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from land subsidence/settlement.

As discussed under Impact GEO-3a, the proposed project site is outside the subsidence area caused by previous oil extraction in the Port area and would not adversely impact the proposed Project. However, in the absence of proper engineering, proposed structures could be cracked and warped during proposed project operations as a result of saturated, unconsolidated/compressible sediments. During the proposed project design phases, a geotechnical engineer would evaluate the settlement potential in areas where structures are proposed, as discussed for Impact GEO-3a, to reduce the potential for soil settlement. The incorporation of these measures during design and construction would minimize the potential for exposure of damage to structures or risk of injury to people during operations at the project site.

### Impact Determination

The proposed Project would be designed and constructed in compliance with the recommendations of a geotechnical engineer, consistent with implementation of Sections 91.000 through 91.7016 of the Los Angeles Municipal Code, and in conjunction with criteria established by LAHD, and would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury during operations. Therefore, settlement impacts would be less than significant.

### Mitigation Measures

No mitigation is required.

### Residual Impacts

Impacts would be less than significant.

## Impact GEO-4b: Operation of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from expansive soils.

As described under Impact GEO-4a, expansive soil may be present in the proposed project area and may be present in dredged or imported soils used for proposed project grading. Use of expansive soils beneath proposed project foundations, pavement, or behind retaining structures could result in cracking and distress of these structures during the proposed project operations. However, during the design phase, the proposed Project's geotechnical engineer would evaluate the expansion potential associated with onsite soils, as described in Impact GEO-4a to reduce the potential for soil expansion and damage to overlying structures. The incorporation of these measures during design and construction would minimize the potential for exposure of damage to structures or risk of injury to people during operations at the proposed project site.

#### Impact Determination

The proposed Project would be designed and constructed in compliance with the recommendations of the geotechnical engineer, consistent with Sections 91.000 through 91.7016 of the Los Angeles Municipal Code, and in conjunction with criteria established by LAHD, and would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury during operations. Therefore, expansive soil impacts in upland areas would be less than significant.

#### Mitigation Measures

No mitigation is required.

#### Residual Impacts

Impacts would be less than significant.

### Impact GEO-5b: Operation of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from landslides or mudslides.

As described under Impact GEO-5a, a Converse Davis Dixon Associates 1976 geotechnical investigation at Berth 49 south determined that “land slippage” (lateral up to 14 feet and vertical up to 5 feet) occurred due to a landslide that moved on soft, eastward dipping Malaga Mudstone weak bedding planes. Such bedding plane conditions may exist at the proposed project site and a similar bedding plane failure is possible. As discussed under Impact GEO-5a, a geotechnical engineer would evaluate the potential for landslide areas where structures are proposed during the proposed project design phases, to reduce the potential for landslide occurrence during operation.

#### Impact Determination

The proposed Project would be designed and constructed in compliance with the recommendations of a geotechnical engineer, consistent with implementation of Sections 91.000 through 91.7016 of the Los Angeles Municipal Code, and in conjunction with criteria established by LAHD, and would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury. Therefore, landslide potential at the proposed project site during operation would be less than significant.

#### Mitigation Measure

No mitigation is required.

#### Residual Impacts

Impacts would be less than significant.

### Impact GEO-6b: Operation of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from unstable soil conditions from excavation, grading, or fill.

As described under Impact GEO-6a, natural alluvial and marine deposits, as well as anthropogenic artificial fill consisting of dredged deposits or imported soils, would be encountered at the proposed project site. Groundwater (seawater) is present at depths approximately equivalent to mean sea level or roughly 10 feet. Saturated materials near and below this level would be relatively soft and unstable for engineering purposes, requiring implementation of geotechnical remediation to create a stable site configuration for the proposed Project.

A site-specific geotechnical evaluation would be performed during the design phase to provide recommendations for stability of foundations and slopes. Such recommendations would include specification of the material types to be used for fill, compaction specifications, slope inclination, removal of unsuitable material prior to placing fill, and slope armoring with rip-rap/rock to enhance overall stability and work area safety. The incorporation of these measures during design and construction would minimize the potential for exposure of damage to structures or risk of injury to people during operations at the project site.

#### Impact Determination

Groundwater (seawater) is present at depths approximately equivalent to mean sea level or roughly 10 feet deep. Saturated materials near and below this level would be relatively soft and unstable for engineering purposes, requiring implementation of geotechnical remediation to create a stable site configuration. Appropriate geotechnical engineering would substantially reduce the impacts from unstable and saturated soil conditions, and would allow for construction that would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury during operations. Therefore, impacts would be less than significant.

#### Mitigation Measures

No mitigation is required.

#### Residual Impacts

Impacts would be less than significant.

**Impact GEO-7b: Operation of the proposed Project would not destroy, permanently cover, or materially and adversely modify one or more distinct and prominent geologic or topographic features. Such features may include, but not be limited to, hilltops, ridges, hillslopes, canyons, ravines, rock outcrops, water bodies, streambeds, and wetlands.**

As discussed under Impact GEO-7a, the proposed project area is relatively flat and previously disturbed and/or paved. Consequently, there are no prominent geologic or topographic features. Therefore, operation of the proposed Project would not result in any distinct and prominent geologic or topographic features being destroyed or permanently covered.

#### Impact Determination

Because there are no prominent geologic or topographic features at the proposed project site, no features would be destroyed, covered, moved, or modified. There would be no impacts.

#### Mitigation Measures

No mitigation is required.

#### Residual Impacts

No impacts would occur.

## 3.5.4.3.3 Summary of Impact Determinations

Table 3.5-5 summarizes the impact determinations of the proposed Project related to geology and soils. Identified potential impacts may be based on federal, state, and City of Los Angeles significance criteria, LAHD criteria, and the scientific judgment of the report preparers.

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

**Table 3.5-5.** Summary Matrix of Potential Impacts and Mitigation Measures for Geology and Soils Associated with the Proposed Project

| *Environmental Impacts* | *Impact Determination* | *Mitigation Measures* | *Impacts after Mitigation* |
|---|---|---|---|
| **3.5 GEOLOGY AND SOILS** | | | |
| ***Construction*** | | | |
| **GEO-1a:** Construction of the proposed Project would not result | Less than significant | No mitigation is required. | Less than significant |

| *Environmental Impacts* | *Impact Determination* | *Mitigation Measures* | *Impacts after Mitigation* |
|---|---|---|---|
| in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from fault rupture, seismic ground shaking, liquefaction, or other seismically induced ground failure. | | | |
| **GEO-2a:** Construction of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk involving tsunamis or seiches. | Less than significant | No mitigation is required. | Less than significant |
| **GEO-3a:** Construction of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from land subsidence/ settlement. | Less than significant | No mitigation is required. | Less than significant |
| **GEO-4a:** Construction of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from expansive soils. | Less than significant | No mitigation is required. | Less than significant |
| **GEO-5a:** Construction of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from landslides or mudslides. | Less than significant | No mitigation is required. | Less than significant |
| **GEO-6a:** Construction of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from unstable soil conditions from excavation, grading, or fill**.** | Less than significant | No mitigation is required. | Less than significant |
| **GEO-7a:** Construction of the proposed Project would not destroy, permanently cover, or materially and adversely modify one or more distinct and prominent geologic or topographic features. Such features may include, but not be limited to, hilltops, ridges, | No impact | No mitigation is required. | No impact |

| *Environmental Impacts* | *Impact Determination* | *Mitigation Measures* | *Impacts after Mitigation* |
|---|---|---|---|
| hillslopes, canyons, ravines, rock outcrops, water bodies, streambeds, and wetlands. | | | |
| **Operations** | | | |
| **GEO-1b:** Operation of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from fault rupture, seismic ground shaking, liquefaction, or other seismically induced ground failure. | Less than significant | No mitigation is required. | Less than significant |
| **GEO-2b:** Operation of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk involving tsunamis or seiches. | Less than significant | No mitigation is required. | Less than significant |
| **GEO-3b:** Operation of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from land subsidence/settlement. | Less than significant | No mitigation is required. | Less than significant |
| **GEO-4b:** Operation of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from expansive soils. | Less than significant | No mitigation is required. | Less than significant |
| **GEO-5b:** Operation of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from landslides or mudslides. | Less than significant | No mitigation is required. | Less than significant |
| **GEO-6b:** Operation of the proposed Project would not result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury from unstable soil conditions from excavation, | Less than significant | No mitigation is required. | Less than significant |

| Environmental Impacts | Impact Determination | Mitigation Measures | Impacts after Mitigation |
|---|---|---|---|
| grading, or fill. | | | |
| **GEO-7b:** Operation of the proposed Project would not destroy, permanently cover, or materially and adversely modify one or more distinct and prominent geologic or topographic features. Such features may include, but not be limited to, hilltops, ridges, hillslopes, canyons, ravines, rock outcrops, water bodies, streambeds, and wetlands. | No impact | No mitigation is required. | No impact |

## 3.5.4.4 Mitigation Monitoring

No mitigation is required.

## 3.5.4.5 Significant Unavoidable Impacts

All impacts would be less than significant.