4.5 GEOLOGY, SEDIMENTS, AND SEISMICITY

Section 4.5 describes the environmental conditions and impacts analysis of geology, sediments, and seismicity issues associated with the granting of a new off-shore lease to the Amorco Marine Oil Terminal (Amorco Terminal) to continue to operate in the southeastern Carquinez Strait. The environmental setting provides information on the existing geologic and geotechnical conditions regionally, as well as in the immediate vicinity of the Amorco Terminal. Also included is a summary of laws and regulations that may affect geologic resources and seismicity analyses. This is followed by an analysis of the potential Project impacts. Geologic issues associated with renewing the Amorco Terminal lease primarily involve the effects of seismic events on Amorco Terminal structures and systems, including but not limited to pipelines, valves, supports, anchors, and electrical and mechanical equipment.

4.5.1 ENVIRONMENTAL SETTING

The Amorco Terminal is located in Martinez, Contra Costa County, along the southern edge of the Carquinez Strait approximately 0.5 mile southwest of the Benicia-Martinez Bridge, in the seismically active San Francisco Bay Area (Bay Area).

4.5.1.1 Regional Geology

California is located on the boundary between the Pacific and North American Tectonic Plates. The Pacific Plate comprises much of the Pacific Ocean and includes the western edge of the North American continent. The North American Plate includes the remainder of the North American continent and the western half of the Atlantic Ocean. The Pacific Plate is drifting northwesterly relative to the North American Plate, and the main line of contact between these two plates is the San Andreas Fault system.

The Bay Area lies within the geologically active part of the Coast Ranges geomorphic province of California, which is characterized by a series of nearly parallel mountain ranges (Goldman 1969) trending northwest-southeast. Figure 4.5-1 depicts the locations of the major faults that characterize the area. Active faults, including the Concord/Green Valley, West Napa, Calaveras, Hayward, San Gregorio, and San Andreas Faults, are roughly parallel to the western and eastern limits of the Bay Area. The San Francisco Bay itself began forming during the Pleistocene Epoch, approximately 2 million years ago, when the land masses now known as San Francisco and Marin began to tilt eastward along the Hayward Fault, forming a depression that filled with sediment and water.

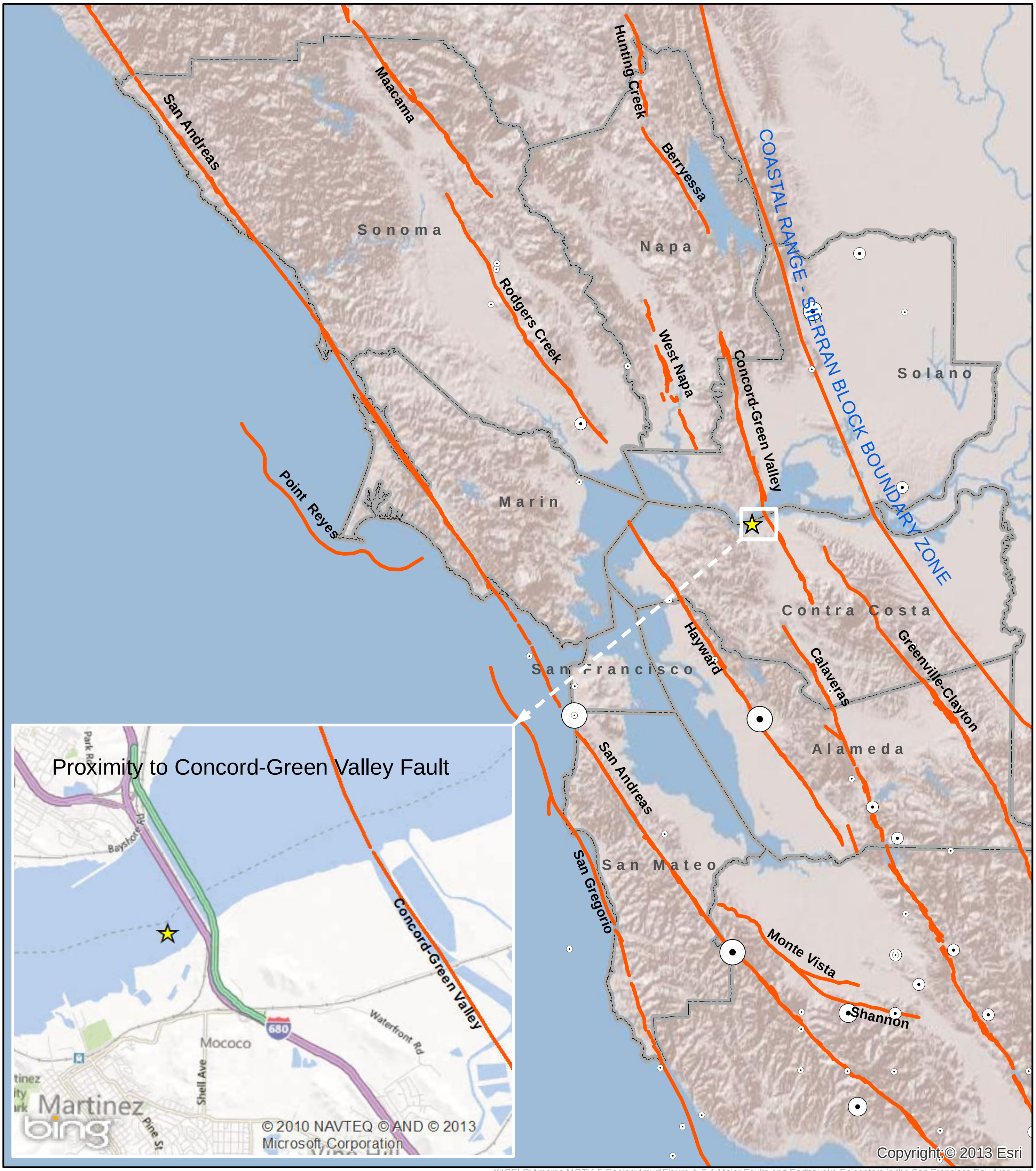
The bedrock units underlying the area east of the Hayward Fault (which includes the Amorco Terminal; see Figure 4.5-1), and west of the Sierran basement rock boundary zone, range from Jurassic-Cretaceous to Quaternary-age (approximately 135 million years old to current). The oldest unit, the Franciscan Formation, is believed to have originated on the Pacific Ocean floor and was welded to the western margin of the American continent by plate movement. Subsequently, it was uplifted through the younger sedimentary rock to form the backbone of the Diablo Range, which is part of the Coast Ranges. The strata of this bedrock formation are highly distorted and partially metamorphosed through heat and compression. The Franciscan Formation primarily consists of interbedded sandstone and shale, limestone, radiolarian chert, and metavolcanic rocks (Goldman 1969).

The Great Valley Sequence, a thick sequence of Mesozoic sandstones and shales that overlies the Franciscan Formation, comprises sedimentary rock formed under ancient seas that once existed on the American continent. The youngest formations are the deposits of Quaternary-age marine sediments, known as “bay mud,” and Quaternary alluvium deposited by stream erosion. Figure 4.5-2 depicts the regional surface geology of the Suisun Bay and Carquinez Strait region near the Project site.

4.5.1.2 Site-specific Geology

The site-specific geologic characteristics described in this section are based on the regional studies of the Bay Area conducted by the California Geological Survey (CGS), formerly known as the California Division of Mines and Geology (Goldman 1969, Treaser 1963), and geotechnical investigations conducted by MACTEC Engineering and Consulting (MACTEC 2005) at the Amorco Terminal. Local surface conditions primarily comprise early Quaternary-age (Pleistocene) alluvium and late Quaternary-age (Holocene) bay mud. Goldman’s (1969) contour maps of the top of bedrock suggest that bedrock lies approximately 80 feet below mean lower low water (MLLW) near the Amorco Terminal shoreline to a depth of approximately 120 feet below MLLW along the Amorco wharf.

Three geotechnical investigations have been conducted to characterize the geology in the vicinity of the Amorco wharf (MACTEC 2005, Treadwell and Rollo 2008, Treadwell and Rollo 2010). Treadwell and Rollo (2010), in a geotechnical report that compiled geologic boring data from all previous investigations, concluded that approximately 15 to 20 feet of recently deposited soils, characterized as dredged spoils/bay sediments, exist in the area under the Amorco wharf. The report indicates that approximately 40 to 56 feet of compressible clay, characterized as bay mud, underlies the recent deposits. Stiff clays with occasional thin lenses of sand and gravel, described as older bay deposits, were encountered beneath the bay mud at thicknesses ranging from approximately 10 to 30 feet. Bedrock was encountered approximately 98 feet below the mudline, dipping from northeast to southwest. In general, the bedrock was found to consist of moderately to deeply weathered, weak to moderately strong claystone and siltstone, interbedded with layers of crushed to intensely fractured sandstone.



X:\CSLC\Amorco MOT\4.5 Geology\mxd\Figure 4_5-1 Major Faults and Earthquake Epicenters in the San Francisco Bay Area.mxd

Figure 4.5-1 Major Faults and Earthquake Epicenters in the San Francisco Bay Area
California State Lands Commission
Amorco Marine Oil Terminal Lease

8/14/2013

Earthquake Epicenter
Magnitude
- 5.5 - 5.9
- 6.0 - 6.4
- 6.5 - 6.9
- 7.0 +
- Fault Lines
- Approximate Terminal Location

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1:1,000,000
1 inch = 16 miles
0 5 10 mi

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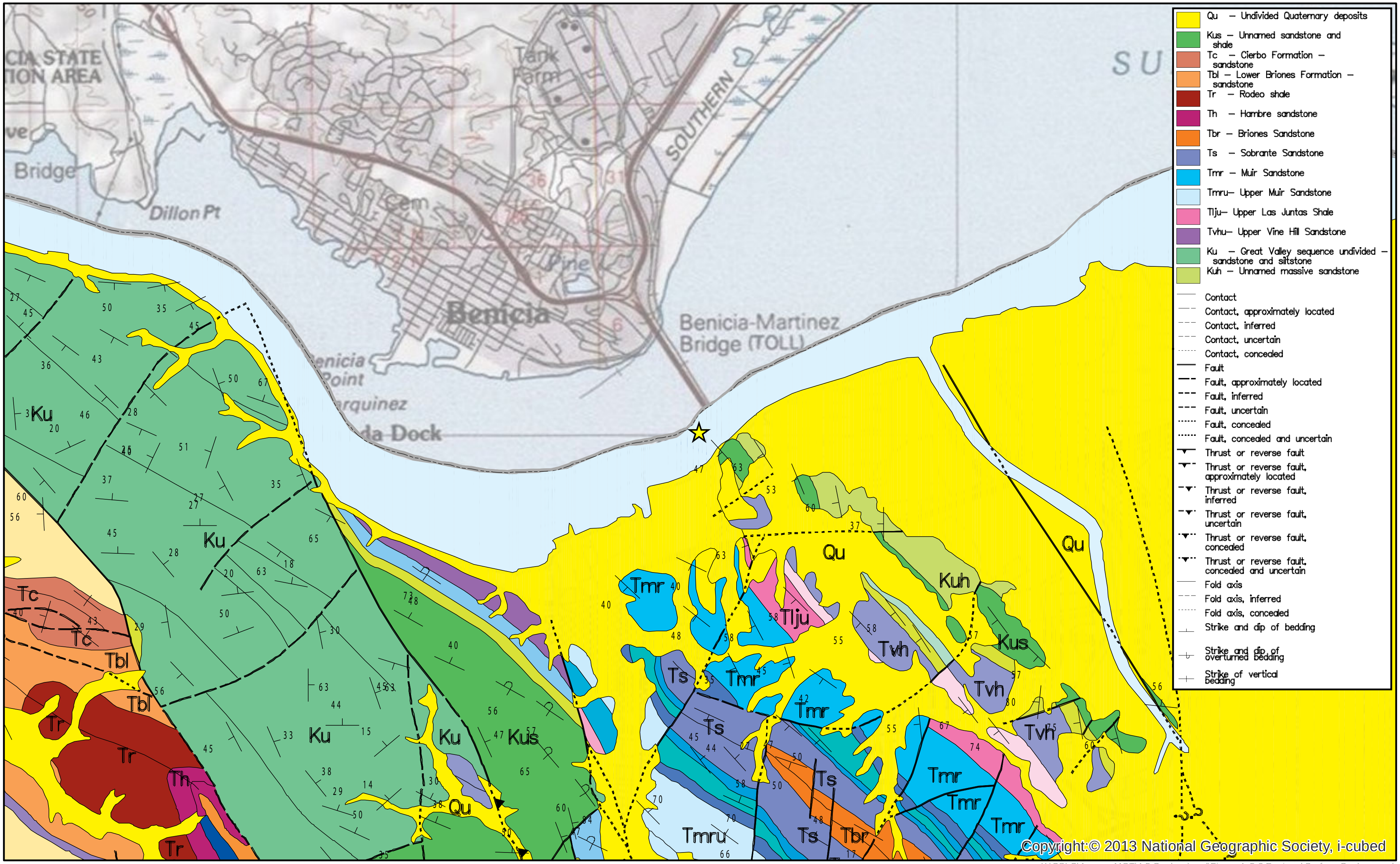

X:\CSLC\Amorco MOT\4.5 Geology\mxd\Figure 4_5-2 Regional Surface Geology.mxd

Figure 4.5-2
Regional Surface Geology
California State Lands Commission
Amorco Marine Oil Terminal Lease Consideration Project

TRC

8/14/2013

☆ Amorco Terminal Location

1:60,000

1 inch = 5,000 feet

0 0.5 1 mi

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4.5.1.3 Regional Seismicity

As discussed in Section 4.5.1.1, the San Francisco Bay Area lies along the San Andreas Fault, which forms the boundary between the Pacific and North American Tectonic Plates. Movement between the plates has created several other active faults parallel to the San Andreas, including the Hayward, Calaveras, Greenville, Concord/Green Valley, Rodgers Creek, and San Gregorio Faults. These faults create a zone approximately 50 miles wide through the greater San Francisco Bay Area. Table 4.5-1 shows data and locations for known active faults in the Amorco Terminal vicinity.

Table 4.5-1: Known Active Faults in the Amorco Terminal Vicinity

Fault	Approximate Distance from Site (miles)	Estimated Maximum Moment Magnitude (Mw)	Slip Rate (mm/year)[1]	Approximate Recurrence Interval (years)
Concord/Green Valley	1.75	6.9	6	200
West Napa	11.0	6.9	1	700
Hayward	11.6	7.1	9	160
Rogers Creek	11.6	7.0	9	200
Great Valley (segments 4 to 6)	15.1 to 18.7	6.5 to 6.7	1.5	475 to 625
Calaveras (north)	16.2	6.8	6	180
Greenville	19.1	6.9	2	620
Hunting Creek	29.3	7.1	6	200
San Andreas	29.6	7.9	24	220
San Gregorio	32.2	7.6	5	450
Point Reyes	37.6	7.0	0.3	3,500
Monte Vista	41.6	6.7	0.4	2,400
Calaveras (south)	44.2	6.2	15	35
Maacama (south)	48.4	6.9	9	220

Sources: Cao et al. 2003, WGCEP 2007

[1]mm/year = millimeters per year

Several major earthquakes have occurred within the Bay Area on many of the major faults. Major earthquakes occurred in 1836 and 1868 along the Hayward Fault, which is located approximately 12 miles from the site. Both earthquakes had estimated moment magnitudes (Mw) of approximately 7. A major earthquake occurred in 1861 on the Calaveras Fault, which is located approximately 16 miles south of the site. This earthquake caused surface rupture for 8 miles through San Ramon Valley and caused severe damage within Contra Costa County. The "Mare Island" earthquake of 1898, along the southern end of the Rodgers Creek Fault, which is approximately 12 miles from the Amorco Terminal, is also of historic significance, with an estimated Mw of 6.2 (Toppozada et al. 1992). The 1838, 1906 (both with an estimated Mw of 7.9), and 1989 ("Loma Prieta"; Mw of 7.1) earthquake events comprise the most significant earthquakes that have occurred in the region within the past 200 years, and caused major damage to structures in the Bay Area. The Working Group on California Earthquake Probabilities (2007) estimates that (1) the Mw of future earthquakes for various faults within the San Andreas system varies from approximately 7.0 to 7.9 (2) there is a 62 percent chance that there will be a damaging earthquake (i.e., Mw of 6.7 or greater) in the San Francisco Bay Area within the next 30 years, and (3) there is a 27 percent chance that there will be a damaging earthquake on the Hayward/Rodgers Creek Fault zone within the next 30 years.

4.5.1.4 Site-specific Seismicity

Active faults, as defined by the CGS (Hart and Bryant 1997), do not transect the Amorco Terminal. An active fault, as defined in the Alquist-Priolo Earthquake Fault Zoning Act (see Section 4.5.2), is one that has experienced surface displacement within the Holocene period (within the last 11,000 years). The Amorco Terminal is surrounded by the Concord/Green Valley Fault to the east, the West Napa and Rodgers Creek Faults to the northwest, the Hayward Fault to the west, and the Calaveras Fault to the south, as shown on Figure 4.5-2. The Concord/Green Valley Fault is located less than 2 miles from the site and is estimated to be able to produce an Mw 6.9 earthquake approximately every 200 years. In the 150-year recorded history, no major earthquake has been recorded on this fault; however, the Working Group on California Earthquake Probabilities (2007) inferred that the entire Concord/Green Valley Fault Zone, which runs beneath Suisun Bay, could rupture in one major event. Several other faults are located between 10 and 20 miles from the Project site, and each of these is believed to be able to produce large earthquakes with a range of approximately Mw 6.5 to 7.0.

The U.S. Geological Survey ([USGS] 2002) developed Probabilistic Seismic Hazard Maps showing expected levels of ground shaking in the form of peak ground acceleration (PGA). The USGS Seismic Hazards Map (see Figure 4.5-3) shows, for California, the level of ground acceleration that has 1 chance in 475 of being exceeded each year, which is approximately equal to a 10 percent probability of being exceeded in 50 years. For the Amorco Terminal area, the expected PGA is approximately 46 percent of the Earth's gravitational force (g), or 0.46 g.

Peak Acceleration (% gravitational-force) with 10% Probability of Exceedance in 50 Years
USGS 2002

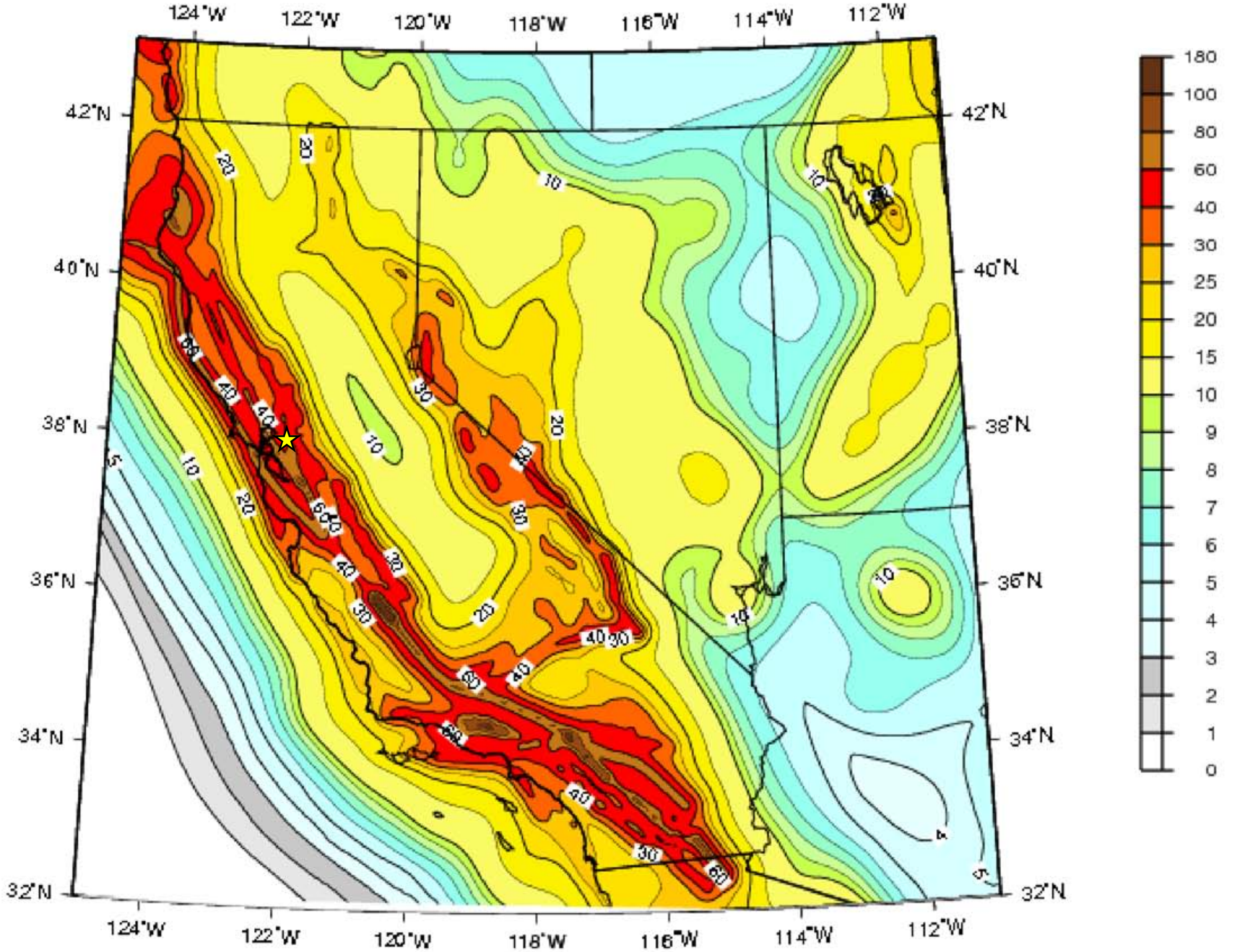

Figure 4.5-3
Seismic Hazard Map, USGS 2002
California State Lands Commission
Amorco Marine Oil Terminal Lease Consideration Project

8/14/2013

☆ Approximate Terminal Location

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The California Department of Transportation (1996) has also developed a Seismic Hazard Map for California showing contours of peak acceleration (see Figure 4.5-4). These contours reflect the effects of the Maximum Credible Events for the various contributing faults, and apply to ground motions for rock or stiff soil. As shown on Figure 4.5-4, a peak acceleration contour of 0.5 g is found in the Amorco Terminal vicinity. Both of these sources provide data that imply that strong ground shaking is likely should a major earthquake on a nearby active fault occur.

4.5.1.5 Tsunamis and Seiches

Tsunamis are sea waves typically created by undersea fault movement or coastal or subsea landslide. Tsunamis may be generated at great distance from shore (far field events) or nearby (near field events). Waves are formed as the displaced water moves to regain equilibrium, and radiates across the open ocean, similar to ripples from a rock being thrown into a pond. When the waveform reaches the coastline, it pushes upward from the ocean bottom to create a high swell of water that breaks and washes inland with velocities as high as 15 to 20 nautical miles per hour (knots). The water mass creates tremendous force and can impacts coastal structures.

A seiche is a long, rolling wave with periodic oscillation or “sloshing” of water in an enclosed basin and can be caused from strong winds. The period of oscillation can range from minutes to hours and have the potential to produce large changes in water levels.

Tsunamis and seiches are both rare. However, tsunamis have historically affected the Pacific coastline. The Fort Point tide gauge in San Francisco recorded approximately 21 tsunamis between 1854 and 1964. The 1964 Alaska earthquake generated a wave height of 7.4 feet near Crescent City, California, causing loss of human life. In March 2011, a 9.0 earthquake that occurred off Japan’s east coast produced a tsunami with waves that came ashore in northern and central California at heights between 4 feet and 8 feet, causing damage to docks and vessels.

A tsunami originating in the Pacific Ocean would lose much of its energy passing through San Francisco Bay. Ritter and Dupre (1972) estimated the run-up for the 100-year return period tsunami near the Golden Gate to be 10 feet. The available data indicate a systematic diminishment of the wave height from the Golden Gate to the head of the Carquinez Strait and on into Suisun Bay. The Marine Oil Terminal Engineering and Maintenance Standards (MOTEMS) (see Section 4.5.2) provides estimated tsunami run-up for areas of California. The maximum credible tsunami water levels and current speeds for the Martinez area are 2.3 feet and 1.3 feet per second, respectively, indicating a muted response to tsunamis than at the Golden Gate. MOTEMS requires that each marine oil terminal has a Tsunami Plan, detailing what actions will be taken to safeguard the facility, in the event of a tsunami threat.

4.5.1.6 Sea-Level Rise

Scientific research to date indicates that observed climate change around the globe will likely result in sea level rise. Sea levels in San Francisco Bay are measured at the San Francisco (Fort Point) tide station. The monthly mean sea levels during the period of 1906 to 2006 show an upward linear trend of approximately 2 millimeters per year (mm/yr). During this period, unusually high spikes are noted due to El Niño episodes. Based on the measured sea level rise of 2 mm/yr, the sea level rise at the Amorco Terminal over a 30-year period is estimated to be 0.2 foot. MOTEMS requires that all marine oil terminals consider, as part of design or upgrades, the predicted sea level rise over the remaining life of a terminal (see Section 4.5.2).

4.5.2 REGULATORY SETTING

Federal and State laws that may be relevant to the Project are identified in Table 4.0-1. Local laws, regulations, and policies are discussed below.

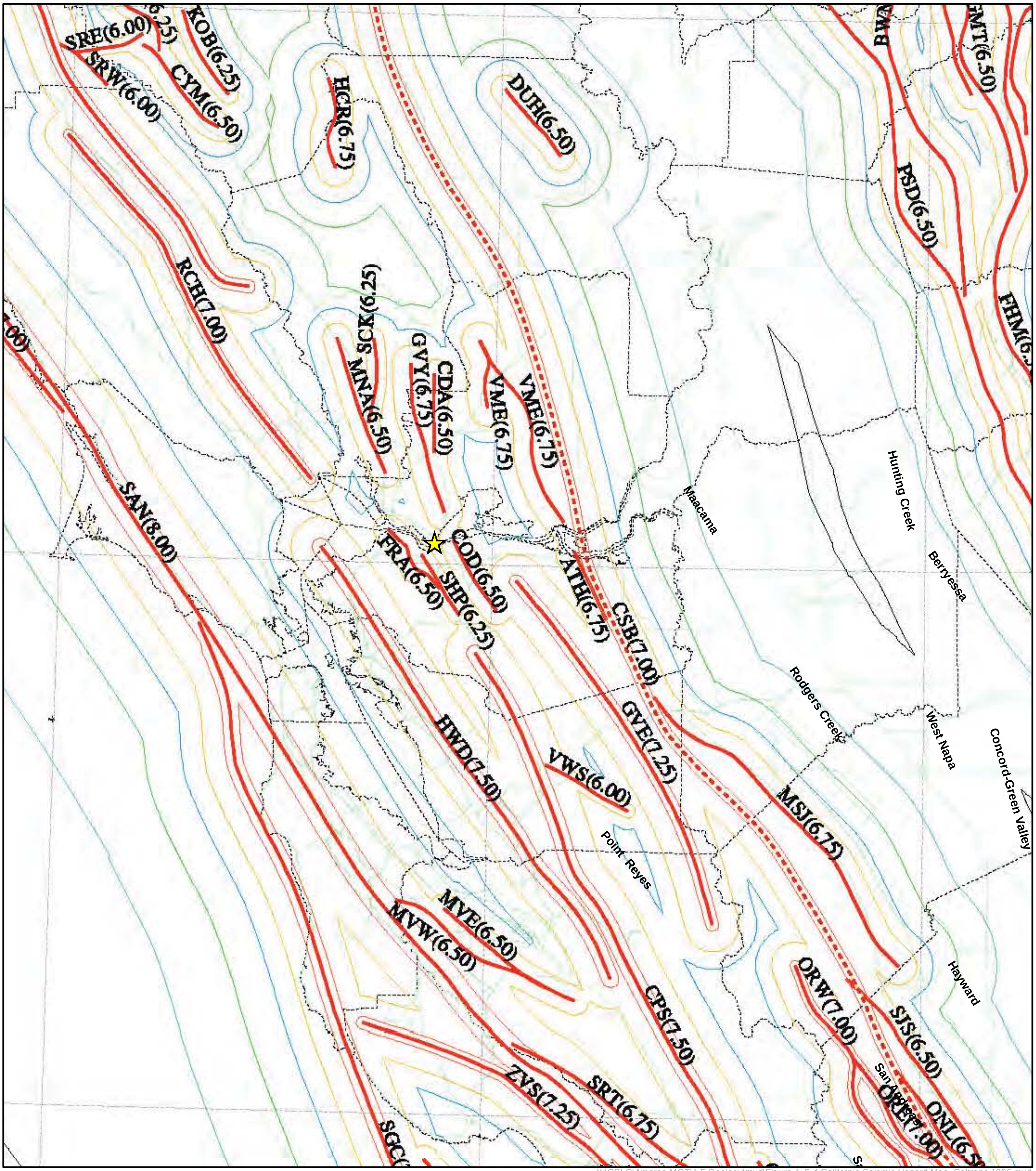
Contra Costa County

Contra Costa Health Services Hazardous Materials Programs administers the California Accidental Release Prevention (CalARP) Program (Cal. Code Regs., tit. 19, Div. 2, Ch. 4.5). Through CalARP, businesses that handle more than a threshold quantity of certain regulated substances must develop a Risk Management Plan (RMP). An RMP is a detailed engineering analysis of the potential accident factors (including seismic considerations) present at a business, and the mitigation measures that can be implemented to reduce this accident potential. Additionally, MOTEMS incorporates CalARP regulations regarding the seismic assessment of anchors and supports on pipelines and valves, and the seismic assessment of existing electrical and mechanical equipment.

City of Martinez

The Safety Element of the City of Martinez General Plan identifies geologic and seismic hazards in the city, provides restraints in the selection of land for development, and provides policies with regard to structural design. The Open Space Element identifies the City's policies pertaining to natural resources, including soils and minerals.

Acceptable design criteria for static and dynamic loading conditions are specified by the International Building Code (IBC). The City has adopted the IBC per Section 15.04.010 of the Municipal Code.



X:\CSLC\Amorco MOT\4.5 Geology\mxd\Figure 4_5-4 California Seismic Hazard Map, Caltrans 1996.mxd

Figure 4.5-4
California Seismic Hazard Map, Caltrans 1996
California State Lands Commission
Amorco Marine Oil Terminal Lease Consideration Project

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0.7g Peak Acceleration Contour
0.6g Peak Acceleration Contour
0.5g Peak Acceleration Contour
0.4g Peak Acceleration Contour
0.3g Peak Acceleration Contour
0.2g Peak Acceleration Contour
0.1g Peak Acceleration Contour
Special Seismic Source (SSS)
Faults with Fault Codes (MCE)
State Highways
County Boundary
Latitude & Longitude
Approximate Terminal Location

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4.5.3 IMPACT ANALYSIS

4.5.3.1 Significance Criteria

For the purposes of this analysis, an impact was considered to be significant and to require mitigation if it would result in any of the following:

- Surface faulting or ground rupture, as a result of a seismic event, that could substantially damage structures or create a risk of injury or loss of life;
- Ground motion due to a seismic event that could induce shaking, slope instability, liquefaction, settlement, or landslides which could substantially damage structures or create a risk of injury or loss of life;
- Tsunamis or seiches that would expose people or structures to the risk of loss, injury, or death;
- Reduction of the structural stability of the wharf due to an increase in loading conditions, vessel size, or number of vessels calling; or
- Construction or maintenance activities that could cause substantial soil erosion or impact to known mineral resources.

4.5.3.2 Assessment Methodology

Geologic impacts were evaluated in two ways: (1) impacts of geologic hazards on project components that may result in substantial damage to structures or infrastructure, or expose people to substantial risk of injury; and (2) the impact of the project on the local geologic environment.

4.5.3.3 Impacts Analysis and Mitigation Measures

Proposed Project

Impact Geology, Sediments, and Seismicity (GSS)-1: Expose people or structures to surface faulting and ground rupture, resulting in substantial structural damage and risk of injury or loss of life. (Less than significant.)

The Amorco Terminal lies outside of the Alquist-Priolo earthquake fault zone, so surface faulting and ground rupture from known active faults is not anticipated, and the impact is, therefore, less than significant. However, significant ground shaking could occur as a result of a major earthquake on a nearby fault; this impact is discussed as GSS-2, below. Accordingly, impacts from surface faulting or ground rupture would be less than significant.

Mitigation Measure: No mitigation required.

Impact GSS-2: Expose people or structures to strong ground shaking, slope instability, and/or seismically induced landslides causing substantial structural damage and risk of injury or loss of life. (Less than significant.)

The Amorco Terminal is subject to strong ground shaking as a result of a major earthquake on any of the nearby faults, described in Section 4.5.1.1. Prior to the recent Amorco wharf upgrades, which were completed in 2013, ground response analysis was performed to develop site-specific seismic design provisions in accordance with the California Building Code (Treadwell and Rollo 2008). These were incorporated into the MOTEMS upgrade design to minimize structural damage due to ground shaking.

Slope stability analysis was also performed for the wharf (Treadwell and Rollo 2008). The results of this study, which used an idealized subsurface profile and soil parameters from the investigation, indicated a relatively low “factor of safety,” i.e., relatively low resistance to slope failure. However, the resulting anticipated ground displacements were small; even with a high level of shaking; the slope deformation was calculated as less than a 0.5 foot. In accordance with MOTEMS, under these conditions the effects of slope deformation can be neglected during structural evaluation of a wharf (Treadwell and Rollo 2008).

The potential for lateral spreading (downslope movement as a result of liquefaction of underlying soils) is considered low due to the low potential for liquefaction of the soils at the site (see Impact GSS-3, below).

Since 2007, Tesoro has been completing MOTEMS-required seismic upgrades at the Amorco wharf. These were completed in June 2013. Because potential seismic events have been considered within the upgrades design, potential adverse impacts are considered to be less than significant.

Mitigation Measure: No mitigation required.

Impact GSS-3: Expose people or structures to liquefaction and seismically induced settlement causing substantial structural damage and risk of injury or loss of life. (Less than significant.)

The results of sampling and laboratory testing and analyses of soils beneath the wharf indicate that the potential for liquefaction at the site is low (Treadwell and Rollo 2008). Therefore, this impact is less than significant.

Mitigation Measure: No mitigation required.

Impact GSS-4: Expose people or structures to the risk of loss, injury, or death as a result of tsunamis and/or seiches. (Less than significant.)

As discussed in Section 4.5.1.5, tsunamis and seiches are rare, and a tsunami originating in the Pacific Ocean would lose most of its energy as it passes through the San Francisco Bay and into the Carquinez Strait. Furthermore, MOTEMS requires marine oil terminals to have a Tsunami Plan to address far-field and near-field tsunami events, notifications and communications, tsunami warning system, tsunami response actions, tidal levels, currents and seiche conditions, loss of utilities, tsunami plan accessibility and training, and post-event inspection. Per MOTEMS, the Tsunami Plan must be revisited and revised, where necessary, at a minimum of every three years. Since minimal damage would be expected to occur to the Amorco wharf, and because Amorco is required to comply with the MOTEMS, impacts are less than significant.

Mitigation Measure: No mitigation required.

Impact GSS-5: Cause structural damage to the Amorco Terminal due to an increase in loading conditions, vessel size, or number of vessels calling. (Less than significant.)

MOTEMS requires mooring and berthing analyses to be performed, such that operational limits are established within the allowable capacities of the structure, fendering system, and mooring arrangements for the various sizes of vessels that are permitted to call at any given terminal. Changed loading conditions, vessel size, or number of vessels calling would not be permitted above the established operating limits, which are based in part on the design capabilities of the wharf structural components. Therefore, this impact is less than significant.

Mitigation Measure: No mitigation required.

Alternative 1: No Project

Impact GSS-6: Elimination of long-term potential for structural damage. (Beneficial.)

Under the No Project Alternative, the Amorco Terminal lease would not be renewed and the existing wharf would be subsequently decommissioned with its components abandoned in place, removed, or a combination thereof. Removal of the structures would not have geotechnical implications or result in geologic impacts. Following decommissioning of the wharf, any potential for structural damage will have been eliminated. The No Project Alternative would likely result in Amorco operations transferred to other Bay Area marine terminals. Those terminals could have the potential for geologic, sediment, and seismic impacts, depending on the specific condition or need for modifications or new construction associated with each terminal.

Mitigation Measure: No mitigation required.

Impact GSS-7: Potential to cause substantial soil erosion, or to impact a known mineral resource. (Less than significant.)

With the absence of the Amorco wharf, modification of existing and new overland pipelines, railways, and roadways would likely be required to deliver crude oil or other products to the Golden Eagle Refinery. Soil erosion or sedimentation during construction activities would be limited by the use of Best Management Practices per a Stormwater Pollution Prevention Plan, which is required by the Regional Water Quality Control Board for any project where one acre or more of land is disturbed. Temporary erosion-control measures would be implemented during the construction period to help maintain water quality, protect property, and prevent accelerated soil erosion. With regard to mineral resources, according to the State Mining and Geology Board Surface Mining and Reclamation Act Designation Report No. 7, the potential mineral deposits in Contra Costa County are located in the cities of Antioch and Byron. Therefore, the likelihood of significant mineral deposits being present along potential new pipelines to the Golden Eagle Refinery is small. For these reasons, impacts are anticipated to be less than significant.

Mitigation Measure: No mitigation required.

Impact GSS-8: Potential to cause damage and/or failure to pipelines as a result of a seismic event. (Less than significant.)

Modification of existing and new overland pipelines would likely be required to deliver crude oil or other products to the Golden Eagle Refinery. Integrity review of pipelines is required by the MOTEMS for pipelines at marine terminals to avoid failures due to seismic displacement, improper engineering design, corrosion, joint failure, and vandalism. Because of the MOTEMS seismic design and operational requirements, the chance of pipeline damage from a seismic event is less than significant. Discussion of the consequences of spills, including impacts to other resources, is presented in various subsections of Section 4.0, Environmental Impact Analysis.

For each pipeline system, pipeline operators are required to prepare and follow a manual of written procedures to ensure safety during pipeline maintenance and normal operations, abnormal operations, and emergencies (49 Code of Federal Regulations [CFR] Part 195.402). The maintenance and normal operations section of the manual must include current maps and records and procedures for operating, maintaining, repairing, starting up and shutting down the pipeline system; minimizing the potential for hazards;

and implementing applicable control room management procedures. The abnormal operations section addresses scenarios where the operating design limits have been exceeded and must include procedures for responding to, investigating and correcting the cause of abnormal operations. The emergencies section of the procedure manual must identify procedures for prompt and effective response, assessing the area impacted by the hazard, and minimizing public exposure to injury. Safety-related condition reports must also be included in the procedures manual and include instructions enabling personnel who perform operation and maintenance activities to recognize conditions that potentially may be safety-related conditions subject to the reporting requirements of 49 CFR 195.55.

> **Mitigation Measure:** No mitigation required above MOTEMS-required engineering design, inspection, and maintenance.

Alternative 2: Restricted Lease Taking Amorco Out of Service for Oil Transport

Impact GSS-9: Potential to cause substantial soil erosion, or to impact a known mineral resource. (Less than significant.)

Refer to Impact GSS-7.

> **Mitigation Measure:** No mitigation required.

Impact GSS-10: Potential to cause damage and/or failure to pipelines as a result of a seismic event. (Less than significant.)

Refer to Impact GSS-8.

> **Mitigation Measure:** No mitigation required above MOTEMS-required engineering design, inspection, and maintenance.

Cumulative Impact Analysis

The shoreline of San Francisco Bay, Carquinez Strait, and Suisun Bay is home to many marine and industrial facilities that are susceptible to earthquake-related damage. The 1989 Loma Prieta earthquake caused extensive damage to various structures in the City of Oakland and its port facilities. Liquefaction and seismically induced settlement of loose and soft soils caused most of the damage, which included failure of bridge supports and damage to storage tanks. Most wharves, however, are constructed with redundancy, and experienced little or no damage during this earthquake. Marine oil terminals in California are designed to withstand large lateral forces and/or are required to upgrade to comply with MOTEMS, and thus are not expected to have significant damage from most earthquake events. Therefore, cumulative impacts, to which the Amorco contributes incrementally, are less than significant.

4.5.4 SUMMARY OF FINDINGS

Table 4.5-2 provides a summary of anticipated impacts and associated mitigation measures.

Table 4.5-2: Summary of Geology, Sediments, and Seismicity Impacts and Mitigation Measures

Impact	Mitigation Measure(s)
Proposed Project	
GSS-1: Expose people or structures to surface faulting and ground rupture, resulting in substantial structural damage and risk of injury or loss of life.	No mitigation required.
GSS-2: Expose people or structures to strong ground shaking, slope instability, and/or seismically induced landslides causing substantial structural damage and risk of injury or loss of life.	No mitigation required.
GSS-3: Expose people or structures to liquefaction and seismically induced settlement causing substantial structural damage and risk of injury or loss of life.	No mitigation required.
GSS-4: Expose people or structures to the risk of loss, injury, or death as a result of tsunamis and/or seiches.	No mitigation required.
GSS-5: Cause structural damage to the Amorco Terminal due to an increase in loading conditions, vessel size, or number of vessels calling.	No mitigation required.
Alternative 1: No Project	
GSS-6: Elimination of long-term potential for structural damage.	No mitigation required.
GSS-7: Potential to cause substantial soil erosion, or to impact a known mineral resource.	No mitigation required.
GSS-8: Potential to cause damage and/or failure to pipelines as a result of a seismic event.	No mitigation required above MOTEMS-required engineering design, inspection, and maintenance.
Alternative 2: Restricted Lease Taking Amorco Out of Service for Oil Transport	
GSS-9: Potential to cause substantial soil erosion, or to impact a known mineral resource.	No mitigation required.
GSS-10: Potential to cause damage and/or failure to pipelines as a result of a seismic event.	No mitigation required above MOTEMS-required engineering design, inspection, and maintenance.