4.7 Geology/Soils/Seismic/Topography

This section considers the potential of the project alternatives to have adverse effects related to geologic and soils related issues. Characterization of geologic resources found in the study area included a review of several published and online maps and reports presenting data on regional geology, seismic hazards, and faulting.

4.7.1 | Regulatory Setting

4.7.1.1 | STATE REGULATIONS

The State of California enacted the Alquist-Priolo State Special Studies Zone Act in 1972 to mitigate the hazard of surface faulting to structures intended for human occupancy. The State has amended the Act 10 times and renamed it the Alquist-Priolo Earthquake Fault Zone (APEFZ) Act in 1994. The APEFZ Act's main purpose is to prevent the construction of structures used for human occupancy on the surface trace of active faults as documented in Special Publication 42 by California Geological Survey (CGS). The APEFZ Act only addresses the hazard of surface fault rupture and is not directed toward other earthquake hazards.

The Seismic Hazards Mapping Act of 1990 was enacted, in part, to address seismic hazards not included in the APEFZ Act, including strong ground shaking, landslides, and liquefaction. Under this Act, the State Geologist is assigned the responsibility of identifying and mapping seismic hazards. CGS Special Publication 117A, adopted in 2008 by the State Mining and Geology Board, enumerates guidelines for evaluating seismic hazards other than surface faulting, and also recommends certain measures as required by Public Resources Code Section 2695 (a). The CGS seismic hazard zone maps use a ground-shaking event that corresponds to 10 percent probability of exceedance in 50 years.

RESOURCES

For information on the APEFZ Act go to:
http://www.conservation.ca.gov/cgs/rghm/ap/Pages/main.aspx

For information regarding the Seismic Hazards Zonation Program go to:
http://www.conservation.ca.gov/cgs/shzp/Pages/Index.aspx

4.7.2 | Affected Environment

4.7.2.1 | TOPOGRAPHY

The Geary corridor extends east-west across moderately hilly terrain near the north end of San Francisco. Elevations along the majority of the route typically vary from 125 feet to 275 feet above mean sea level (amsl) with an average elevation of 200 feet amsl. The highest elevations are near the west end (about 43rd Avenue) and near the central portion (near intersection of Masonic Avenue and Geary Boulevard). Each area is approximately 270 feet amsl. The east terminus of the Geary corridor descends to slightly above sea level east of Market Street near the Transbay Transit Center.

4.7.2.2 | GEOLOGY

The Geary corridor is located within the San Francisco Bay portion of the Coast Ranges geomorphic province of California, a region characterized by northwest-trending ridges and intervening valleys that parallel the seismically active San Andreas and associated faults. The San Francisco Bay Area is known as one of the most seismically active areas in the United States. Earthquakes are generated by a global plate tectonics transform boundary between the northwest-moving Pacific Plate on the west and the North American Plate on the east. The San Andreas Fault zone is recognized as surface expression of this complex tectonic boundary.

As shown in Figure 4.7-1, the vast majority of the Geary corridor is underlain by dune sand (Qds). Hills within the Geary corridor are underlain by bedrock. The underlying bedrock layers (further discussed in Section 4.7.2.2.1 below) have been uplifted, fractured, faulted, and deformed most recently from the San Andreas style of tectonics. Depending upon the location, the bedrock is covered in layers (or mantled) by various surficial deposits consisting of artificial fill (both modern and historic), relatively thick accumulations of native soils, Bay Mud, dune sand, alluvium, slope debris and ravine fill, and landslides (Blake et al. 2000 and Schlocker et al. 1958).

4.7.2.2.1 BEDROCK

Most of the original ground surface along the Geary corridor is blanketed by Late Pleistocene to Holocene eolian deposits or dune sand

Where the original shoreline has been historically modified at the extreme east end of the Geary corridor, artificial fill has been mapped from approximately Market Street to the present shoreline to the east of Market Street.

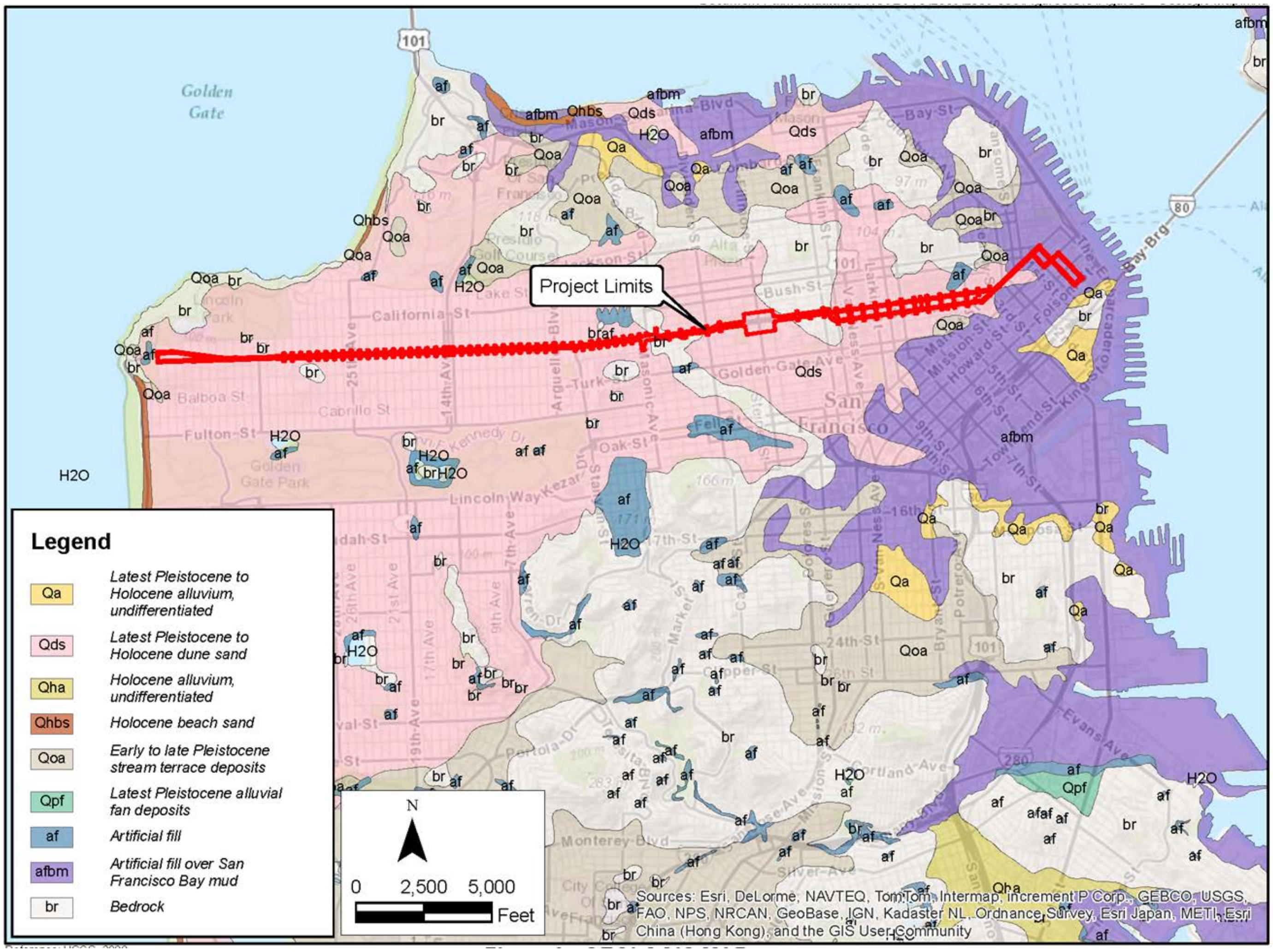
The San Francisco peninsula is underlain by a variety of rock types that collectively make up the Franciscan Complex of the Jurassic-Cretaceous age. The Franciscan Complex is one of the most widespread bedrock formations in California. The formation generally includes chert, graywacke sandstone, greenstone, serpentine, shale, metasedimentary rocks, and sheared rocks in a clayey matrix. The variety of rock types and appearances are understood to be the result of accumulation at the boundary of multiple tectonic plates (Blake et al. 1974, Ellen and Wentworth 1995, Schlocker 1974, and Wagner et al. 2005).

As depicted in Figure 4.7-1, published geologic maps indicate only a few bedrock outcrops exposed along the Geary corridor. These bedrock outcrops are located in the central portion of the corridor near the intersection of Masonic Avenue and Geary Boulevard and east of the central portion near the intersection of Gough Street and Geary Boulevard. At both locations, sheared rocks in a clayey matrix or mélange, and interbedded shales and sandstones are exposed (Blake et al. 1974; Blake et al. 2000; Ellen and Wentworth 1995; Schlocker 1974; and Schlocker et al. 1958).

4.7.2.2.2 SURFICIAL DEPOSIT

The original Geary Boulevard was established sometime before 1900, and the native materials exposed along the alignment have likely been modified to some extent as part of the roadway construction (USGS 1899). Probably the most dramatic alteration of the native materials along the proposed transit alignment is at the east end of the Geary corridor, where the original shoreline was modified beginning in the early 1850s. The original shoreline was near the intersection of First Street and Market Street, but was extended by human activity to its present limits (the Embarcadero). Surficial deposits along the Geary corridor are discussed in detail below.

Figure 4.7-1 Geologic Map



The isolated bedrock hills scattered throughout San Francisco are located between now-buried erosional ravines and canyons that once drained into the Pacific Ocean to the west and into the San Francisco Bay to the north and east. The Geary corridor crosses at least five such paleo-canyons. These are filled with a variety of surficial deposits that typically range from 100 to 200 feet thick. However, the bottom of the deepest buried canyon (at the extreme east end of the Geary corridor near the current shoreline) is approximately 250 feet below sea level (Schlocker 1974).

The various deposits exposed at the ground surface along the Geary corridor are summarized below and shown on Figure 4.7-1. The buried canyons and ravines that mark erosional channels have been backfilled with deeper deposits that may or may not reflect the material exposed along the ground surface. These deeper deposits extend to depths ranging from 100 to 200 feet below the existing ground surface. Subsurface data was reviewed from borings published by the CGS (Blake et al. 1974; Blake et al. 2000; Helley and Lajoie 1979; Schlocker 1974; and Schlocker 1958).

- **Qds** - Most of the original ground surface along the Geary corridor is blanketed by Late Pleistocene to Holocene eolian deposits or dune sand. The sands were blown inland from Pleistocene beaches located west of the current Pacific shoreline.
- **af and afbm** - Where the original shoreline has been historically modified at the extreme east end of the Geary corridor, artificial fill has been mapped from approximately Market Street to the present shoreline to the east of Market Street. The fill is resting on bay mud. The materials used to construct the artificial fills are highly variable and generally consist of clay, silt, sand, and gravel with concrete, brick, and wood debris.

4.7.2.3 | SEISMICITY

The Geary corridor is located in a seismically active region with a history of strong earthquakes (CGS, 2000a). Although no active faults are known to cross the Geary corridor, several major active faults are mapped within 30 miles including the San Andreas, Hayward, Calaveras, and San Gregorio faults. Movement of any one these faults has the potential to result in ground motion in and around the Geary corridor.

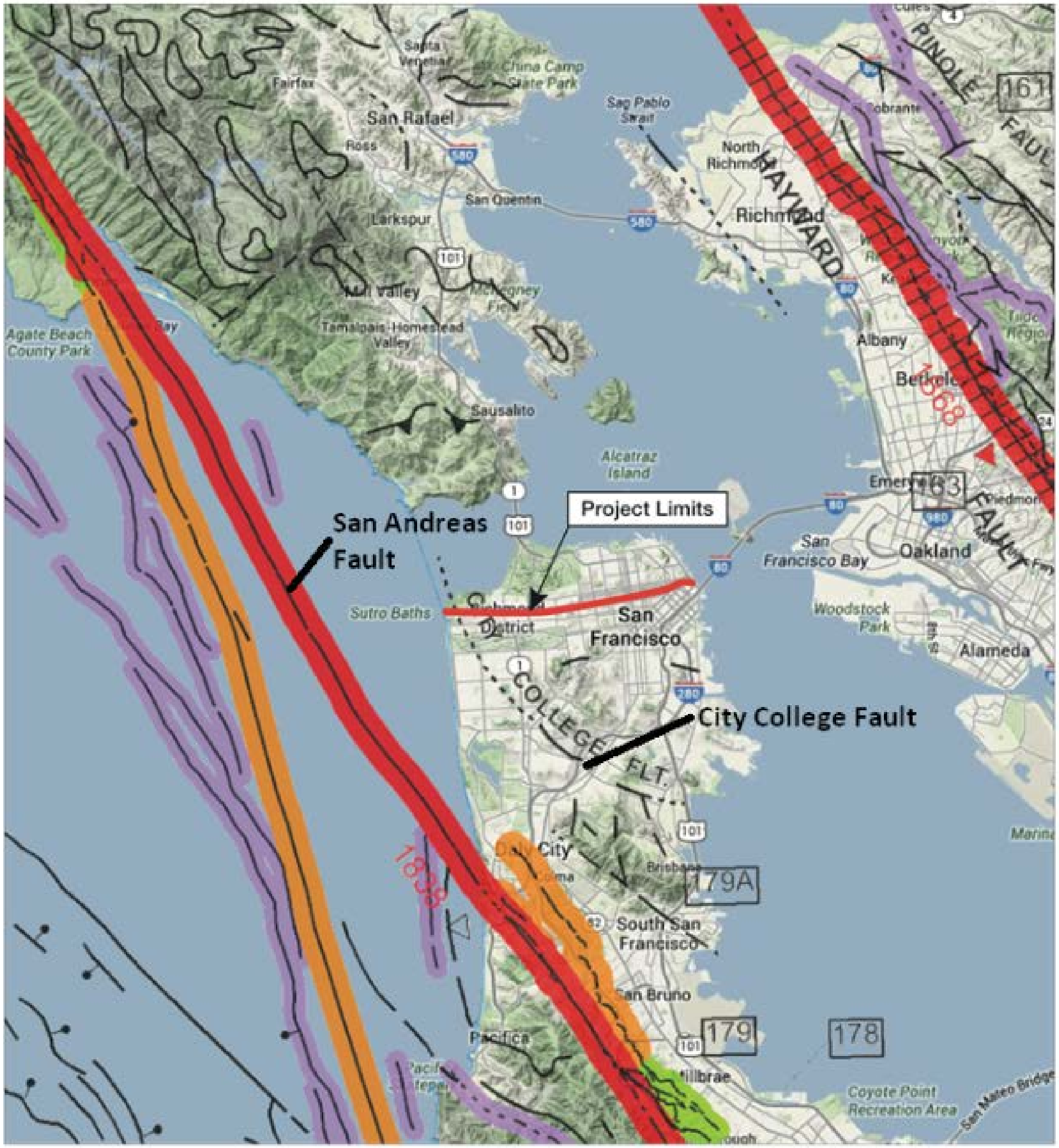
4.7.2.3.1 FAULTING AND EARTHQUAKE POTENTIAL

People standing in Union Square directly following the Loma Prieta Earthquake

Photo: SF Gate

As depicted in Figure 4.7-2, the San Francisco Bay Area is dominated by the northwest-striking, right-slip San Andreas Fault and related major faults, such as the San Gregorio, Hayward-Rodgers Creek, Calaveras, Concord-Green Valley, West Napa, and Greenville-Marsh Creek Faults. The San Andreas and related faults work as a major shear system up to 50 miles wide, accommodating approximately 32 millimeters per year (mm/yr) of slip between the Pacific and North American tectonic plates, with most of this movement occurring along the San Andreas Fault.

Figure 4.7-2 Regional Fault Map



Source: USGS, 2010.

Legend

- Fault along which historic displacement (last 200 years) has occured.
- Holocene fault displacement (during past 11,700 years) without historic record.
- Late Quaternary Fault displacement (during past 700,000 years).
- Quaternary fault (age undifferentiated)
- Pre-Quaternary Fault

N

0 2.5 5 MILES

The Geary corridor is not located within any active Earthquake Fault Zone

The Geary corridor is not located within an Earthquake Fault Zone as designated by the State of California for active faults. No mapped active faults cross the Geary corridor. As shown in Figure 4.7-2, the closest active fault to the Geary corridor is the San Andreas Fault, located approximately 6.7 miles to the southwest. Several inactive faults are mapped across the San Francisco peninsula, three of which cross the Geary corridor as shown on the various published geologic maps (Blake et al. 1974 and 2000; Schlocker 1974; Schlocker 1958). These other faults have not been identified as being seismically active according to criteria established by CGS (Hart and Bryant 1997). These other mapped faults include the northwest-striking City College Fault, located near the intersection of Geary Boulevard and 42nd Avenue. The other two inactive faults are unnamed, and cross the central portion of the Geary corridor near Arguello Boulevard and further to the east near Divisadero Street. The locations of the two, unnamed, inactive faults are not accurately known, and are thus not shown on Figure 4.7-2.

4.7.2.3.2 SURFACE FAULTING / GROUND RUPTURE HAZARD

The San Andreas fault is the nearest mapped active fault, approximately 6.7 miles to the southwest

Fault rupture occurs when a fault plane actually breaks the ground surface during large magnitude earthquakes causing horizontal and/or vertical movements at the surface. As noted above, three mapped but inactive faults cross the Geary corridor and no portion of the Corridor is within any State of California Earthquake Fault Zone (Blake et al. 1974; Blake et al. 2000; Schlocker 1974; and Schlocker 1958). The nearest mapped active fault, the San Andreas Fault, is located approximately 6.7 miles to the southwest.

4.7.2.3.3 SEISMIC GROUND MOTION

The Geary corridor is located within a seismically active region of California. Several active faults are located within 30 miles of the Geary corridor; however, no known active faults actually cross any part of the Geary corridor. Table 4.7-1 lists major active faults in the vicinity of the Geary corridor. Earthquakes on any of these major faults have the potential to cause some seismic ground motion along the Geary corridor.

Table 4.7-1 Major Fault Characterization in the Vicinity of the Geary Corridor

FAULT	APPROXIMATE DISTANCE*	MAXIMUM MOMENT MAGNITUDE EARTHQUAKE
San Andreas (Peninsula)	6.7	7.1
San Andreas (North Coast)	9.1	7.6
Northern Hayward	12	6.9
Southern Hayward	14	6.9
Rodgers Creek	22	7.0
Northern Calaveras	23	6.8
Concord – Green Valley	26	6.9
Monte Vista – Shannon	28	6.8
West Napa	28	6.5
Greenville	30	6.9

* Distances measures from center of project alignment.

Source: Jennings and Bryant 2010

4.7.2.3.4 LIQUEFACTION POTENTIAL AND SEISMIC SETTLEMENTS

Liquefaction occurs when saturated, low relative density, low plasticity materials are transformed from a solid to a near-liquid state. This phenomenon occurs when moderate to severe ground shaking causes pore-water pressure to increase. Site susceptibility to liquefaction is a function of the depth, density, soil type, and water content of granular sediments, along with the magnitude and frequency of earthquakes in the surrounding region. Saturated sands, silty sands, and unconsolidated silts within 50 feet of the ground surface are most susceptible to liquefaction. Liquefaction-related phenomena include lateral spreading, ground oscillation, flow failures, loss of bearing strength, subsidence, and buoyancy effects. Lateral spreading is a form of horizontal displacement of soil toward an open channel or other "free" face, such as an excavation boundary. Lateral spreading can result from either the slump of low cohesion and unconsolidated material or more commonly by liquefaction of either the soil layer or a subsurface layer underlying soil material on a slope, resulting in gravitationally driven movement. Earthquake shaking leading to liquefaction of saturated soil can result in lateral spreading where the soil undergoes a temporary loss of strength. As shown in Figure 4.7-3, the Geary corridor east of Grant Avenue is highly susceptible to liquefaction.[1]

DEFINITION

LIQUEFACTION: When saturated, cohesionless soils lose their strength due to the build-up of excess pore water pressure, especially during cyclic loadings (i.e., shaking) such as those induced by earthquakes

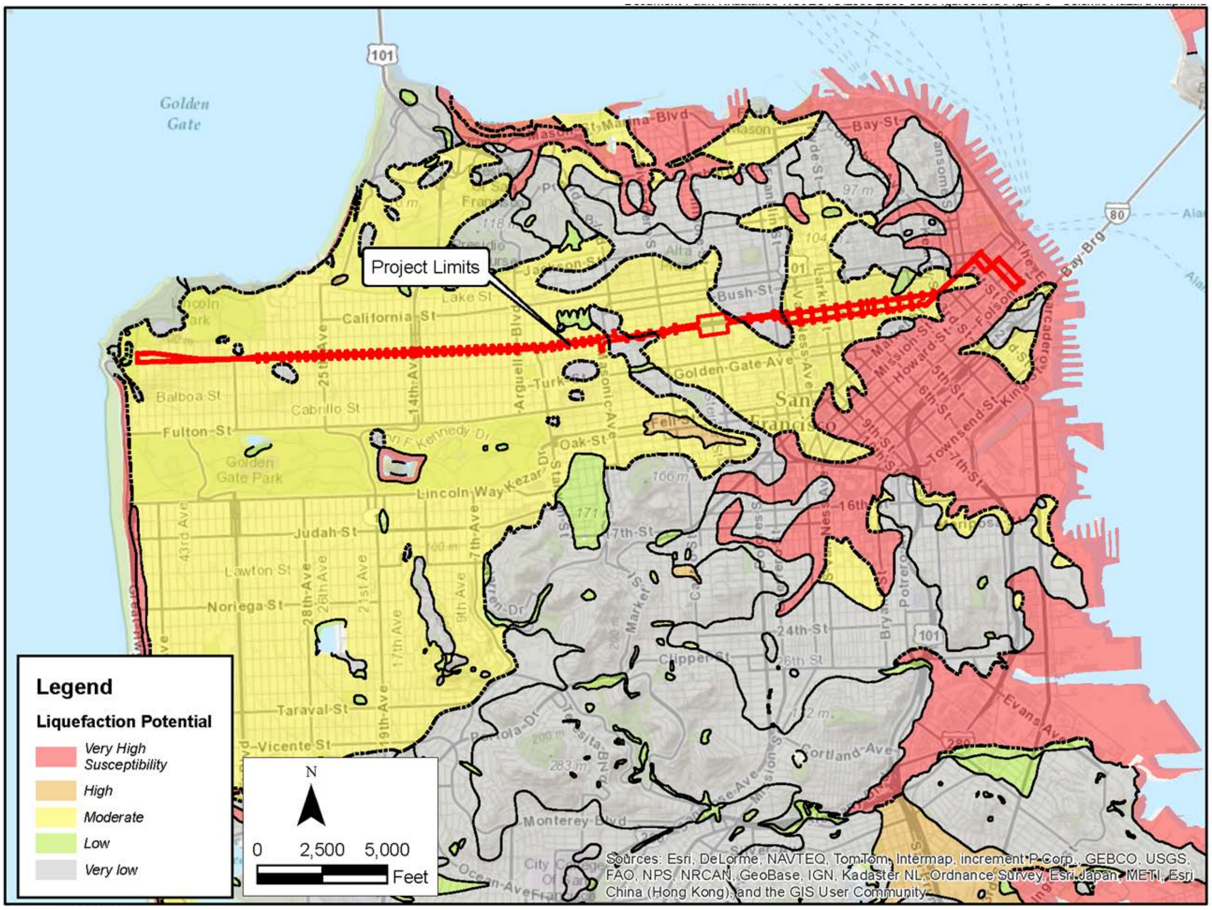
Sand boils and lateral spreads have been documented near the old San Francisco Bay shoreline at the east end of the Geary corridor from both the 1868 Hayward and the 1906 San Francisco earthquakes (Knudsen et al. 1997, and Youd and Hoose 1978). Judging from documented cases from historic earthquakes, the potential for liquefaction and lateral spreading is considered to be very high at the east end of the Geary corridor in the vicinity of the historic San Francisco Bay shoreline.

As shown in Figure 4.7-3 below, the potential for liquefaction to occur along the remainder of the Geary corridor (i.e., west of the historic limit of the San Francisco Bay shoreline) is considered to be moderate.

The potential for lateral spreading along this remainder of the proposed route is considered nonexistent due to the lack of open channels or other free faces of land in this area.

[11] City and County of San Francisco General Plan. 2012. Community Safety Element.

Figure 4.7-3 Liquefaction Potential Map



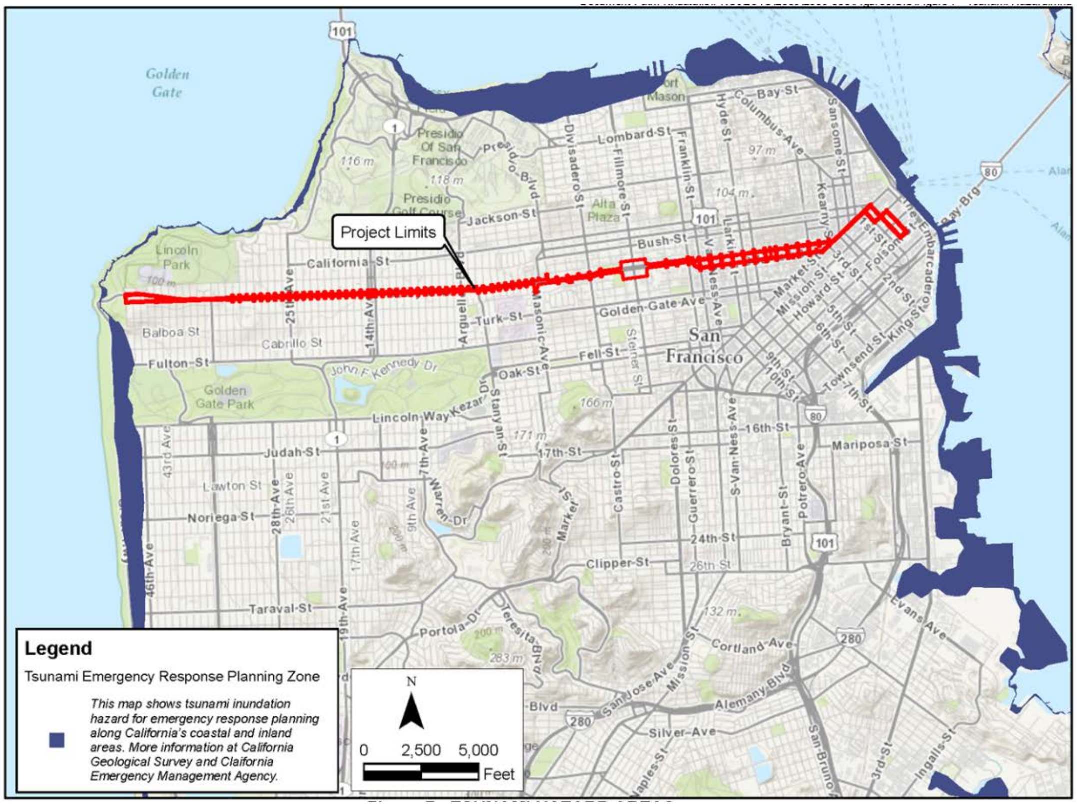
4.7.2.3.5 TSUNAMI

RESOURCE

To see the ABAG tsunami evacuation planning map for San Francisco and San Mateo counties, go to: http://gis.abag.ca.gov

A tsunami occurs when there is a major disturbance in ocean waters, usually from large earthquakes displacing tectonic sea floor plates, but they can also be caused by undersea landslides and rare extraterrestrial events (asteroid impacts). Both local and more distant earthquake sources have been evaluated for potential tsunami effects on the California and San Francisco Bay Area coastline. As shown in Figure 4.7-4, the Geary corridor is located a significant height above the mapped tsunami inundation zone, including the near-sea level portion at the east end of the corridor.

Figure 4.7-4 Tsunami Hazard Areas



4.7.2.4 LANDSLIDE AND SLOPE INSTABILITY

The Geary corridor is not within a designated City and County of San Francisco Landslide Hazard Area.[2] The closest Landslide Hazard Area is located to the south between Stanyan Street and Masonic Avenue in the vicinity of two previous slope failures (landslides at Parker Avenue between Turk and Anza Streets approximately 700 feet to the south of Geary Boulevard and at Turk Street near Baker Street approximately 1,300 feet south of the Geary corridor). The landslide at Parker Avenue appears to have failed in a westerly direction and not toward the proposed transit alignment.

A major landslide or slope failure is not likely to occur along the Geary corridor

Periods of intense rainfall from winter storms have been known to cause landslides in the San Francisco Bay area. No landslides or slope failures within or adjacent to the Geary corridor were triggered by the widespread January 3-5, 1982 rainstorm that affected many areas of the San Francisco Bay Area (Ellen and Wieczorek 1988). Similarly, no landslides have been reported within or near the Geary corridor from the 1997-1998 El Niño rainy season (Hillhouse and Godt 1999).

Landslides generated by earthquake shaking were well documented in the Santa Cruz Mountains as a result of the 1989 Loma Prieta Earthquake, located approximately 61 miles south of the Geary corridor. As a result, CGS has evaluated the landslide potential for the San Francisco Bay area and other areas of California during a seismic event. A series of geologic hazard maps have been published under the Seismic Hazards Mapping Act of 1990 (Chapter 7.8, Division 2 of the California

[2] San Francisco *General Plan*. 2012. Community Safety Element.

Public Resources Code). The maps show that the Geary corridor is not within a CGS Seismic Hazard Zone for Earthquake-Induced Landslides. The closest such zone is approximately 500 feet south of the central portion of Geary Boulevard between Masonic Avenue and Stanyan Street (CGS, 2000a).

No seismically induced landslides have been mapped or reported at or adjacent to the Geary corridor during historic earthquakes, such as the 1868 Hayward or the 1906 San Francisco earthquakes. Likewise, no seismically induced landslides have been documented at or adjacent to the Geary corridor from the more recent 1989 Loma Prieta Earthquake (Knudsen et al. 1997; Keefer and Manson 1998; and Youd and Hoose 1978). Therefore, the potential for earthquake-induced landslides to effect the Geary corridor is considered to be low.

4.7.2.5 | MINERAL RESOURCES

There are no potential sources of mineral resources identified within the Geary corridor

According to records of the California Department of Conservation, no oil or gas exploration or pumping has occurred in or in the area around the Geary corridor.[3]

There are no potential sources of mineral resources identified within the Geary corridor. Historically, there have been several rock quarry operations located throughout the San Francisco peninsula. The closest of these, active from the late 1800s through the early 1900s, was located along the east side of Telegraph Hill approximately 1 mile to the north of the eastern terminus of the Geary corridor. The nearest economical sources for potential crushed rock are located approximately 5 miles to the south, outside San Francisco.

4.7.3 | Methodology

The alternatives were evaluated for potential geologic and seismic-related effects in terms of several risk considerations. The alternatives have the potential to result in construction period and/or operational period effects as noted below.

Construction-Related Effects

- Slope instability
- Seismic risks related to filling the Fillmore Street underpass

Construction and Operational-Related Effects

- Strong ground shaking
- Liquefaction

Potential effects related to the seismic hazards listed above were evaluated in terms of likelihood of occurrence and proposed activity and/or structure location and stability.

This analysis considered geologic landscape along the Geary corridor existing as of 2013, as well as within the broader San Francisco Bay Area, using available geologic data from USGS, CGS, and other published and online maps and reports presenting data on regional geology, seismic hazards, and faulting.

[3] Wildcat Maps and the California Department of Conservation Division of Gas and Geothermal Resources (DOGGR) digital wells database.

4.7.4 | Environmental Consequences

The Geary corridor, like other sites in Northern California, would be subjected to strong ground shaking and liquefaction induced ground settlement and/or differential compaction (settlement due to densification) during a seismic event. Portions of the Geary corridor also could expose people or structures to adverse effects from liquefaction-induced ground failures.

This section describes potential impacts and benefits for geology. The analysis compares each build alternative relative to the No Build Alternative.

As set forth in Section 4.7.4.1, the modifications to the Hybrid Alternative/LPA since publication of the Draft EIS/EIR do not change the conclusions regarding geology impacts in the Draft EIS/EIR.

4.7.4.1 | HYBRID ALTERNATIVE/LPA MODIFICATIONS: ANALYSIS OF POTENTIAL ADDITIVE EFFECTS SINCE PUBLICATION OF THE DRAFT EIS/EIR

As discussed in Section 2.2.7.6, the Hybrid Alternative/LPA now includes the following six minor modifications added since the publication of the Draft EIS/EIR:

1) Retention of the Webster Street pedestrian bridge;
2) Removal of proposed BRT stops between Spruce and Cook streets (existing stops would remain and provide local and express services);
3) Addition of more pedestrian crossing and safety improvements;
4) Addition of BRT stops at Laguna Street;
5) Retention of existing local and express stops at Collins Street; and
6) Relocation of the westbound center- to side-running bus lane transition to the block between 27th and 28th avenues.

This section presents analysis of whether these six modifications could result in any new or more severe impacts related to geology and soils during construction or operation. As documented below, the Hybrid Alternative/LPA as modified would not result in any new or more severe geologic or seismic impacts relative to what was disclosed in the Draft EIS/EIR.

Retention of the Webster Street Pedestrian Bridge

Construction: Site-specific conditions are the primary driver of impacts with regard to geology and soils. This modification would require less construction (i.e. demolition) activity at this location, would occur under the same geologic conditions as described in the Draft EIS/EIR, and does not include any changes that would result in substantially increased geologic hazards. Therefore, this modification would reduce construction-related effects regarding geologic and seismic hazards relative to what was described in the Draft EIS/EIR.

Operation: The Webster Street pedestrian bridge was seismically retrofitted in 1996. Retention of the bridge would maintain existing conditions and, as such, would not result in any increased seismic risk relative to existing conditions. Therefore, this modification would not result in any new or more severe geologic or seismic effects during project operation relative to what was described in the Draft EIS/EIR.

Removal of Proposed BRT Stops between Spruce and Cook Streets

Construction: Site-specific conditions are the primary driver of impacts with regard to geology and soils. This modification would eliminate construction activity outside the curb-to-curb portion of the right-of-way in this area. This modification would occur under the same geologic conditions as described in the Draft EIS/EIR, and does not include any changes that would result in substantially increased geologic hazards. Therefore, this modification would reduce construction-related effects regarding geologic and seismic hazards relative to what was described in the Draft EIS/EIR.

Operation: Retention of the existing bus stops at this location would maintain existing conditions and, as such, would not result in any increased seismic risk relative to existing conditions. Therefore, this modification would not result in any new or more severe geologic or seismic effects during project operation relative to what was described in the Draft EIS/EIR.

Addition of More Pedestrian Crossing and Safety Improvements

Construction: Implementation of additional pedestrian enhancements throughout the corridor would entail localized construction activities where new pedestrian crossing bulbs would be constructed. Site-specific conditions are the primary driver of impacts with regard to geology and soils. This modification would occur under the same geologic conditions as described in the Draft EIS/EIR, and does not include any changes that would result in substantially increased construction-period geologic hazards. Therefore, the addition of more pedestrian enhancements throughout the corridor would not create any new or more severe geologic or seismic impacts during construction.

Operation: During operation, pedestrian enhancements throughout the corridor would be limited to streetscape features and would bear relatively light loads; therefore, the risk of geologic hazards is low. Based on the foregoing, this modification would not create any new or more severe geologic or seismic impacts during operation.

Addition of BRT Stops at Laguna Street

Construction: Additional construction activities would be required to add BRT stops at Laguna Street. Site-specific conditions are the primary driver of impacts with regard to geology and soils. This modification would occur under the same geologic conditions as described in the Draft EIS/EIR, and does not include any changes that would result in substantially increased construction-period geologic hazards. Therefore, the addition of BRT stops at Laguna Street would not create any new or more severe geologic or seismic impacts during construction.

Operation: During operation, BRT stops at Laguna Street would be limited to streetscape features and would bear relatively light loads; therefore, the risk of geologic hazards is low. Based on the foregoing, this modification would not create any new or more severe geologic or seismic impacts during operation.

Retention of Existing Local and Express Stops at Collins Street

Construction: Site-specific conditions are the primary driver of impacts with regard to geology and soils. This modification would eliminate construction activity outside the curb-to-curb portion of the right-of-way in this location. This modification would occur under the same geologic conditions as described in the Draft EIS/EIR, and does not include any changes that would result in substantially increased geologic hazards. Therefore, this modification would reduce construction-related effects regarding geologic and seismic hazards relative to what was described in the Draft EIS/EIR.

Operation: Retention of the existing bus stops at this location would maintain existing conditions and, as such, would not result in any increased seismic risk relative to existing conditions. Therefore, this modification would not result in any new or more severe geologic or seismic effects during project operation relative to what was described in the Draft EIS/EIR.

Relocation of the Westbound Center- to Side-Running Bus Lane Transition

Construction: Relocation of the westbound bus lane transition at 27th Avenue would not alter the total level of construction activities but would shift about half of it one block to the west. Site-specific conditions are the primary driver of impacts with regard to geology and soils. This modification would occur under the same geologic conditions as described in the Draft EIS/EIR, and does not include any changes that would result in substantially increased construction-period geologic hazards. Therefore, the relocation of the transition would not create any new or more severe geologic or seismic impacts during construction.

Operation: Relocation of the bus lane transition would not change bus operations and, as such, would not result in any increased seismic risk relative to what was described in the Draft EIS/EIR; therefore, this modification would not result in any new or more severe geologic or seismic effects during project operation.

4.7.4.2 | NO BUILD ALTERNATIVE – CONSTRUCTION EFFECTS

The No Build Alternative would only include those transit and transportation facilities that are currently planned or programmed to be implemented on the Geary corridor by 2020, which would include but are not limited to the following components subject to strong ground shaking and potential for liquefaction-induced ground failure:

- new concrete paving;
- rehabilitation or resurfacing of existing pavement throughout the Geary corridor;
- replacement of traffic and pedestrian countdown signals;
- construction of curb ramps and pedestrian crossing bulbs.

Soils along the Geary corridor generally appear suitable for construction of elements of the No Build Alternative. The majority of the Geary corridor is located on soils mapped for moderate susceptibility to liquefaction. Features to address seismic-related risks would likely be incorporated into the design of the project components subject to strong ground shaking and potential liquefaction-induced ground settlement, rendering such effects below a level where they would be considered adverse.

Soils in the Geary corridor appear to be suitable for proposed improvements identified in each of the Build Alternatives

The scope of project structures under all alternatives is limited to that of streetscape features that would bear light loads; therefore, the risk from strong ground shaking and liquefaction is low. The design of project features would meet seismic standards, and the project alternatives would not increase the risk of geologic hazards

4.7.4.3 | BUILD ALTERNATIVES – CONSTRUCTION EFFECTS

In the event of an earthquake during project construction, very strong ground shaking could result in slope instability near excavated areas. As a result, each build alternative is susceptible to potential slope instability effects, area-wide potential for ground shaking, and site specific liquefaction, during project construction.

In addition, Alternatives 3 (Center-Lane BRT with Dual Medians and Passing Lanes) and 3-Consolidated (Center-Lane BRT with Dual Medians and Consolidated Bus Service) would include the filling of the underpass at Fillmore Street, decommissioning of the existing pump station at Fillmore Street, and either filling (with inert material) or removing the pump station's fuel tank. There are several seismic-related risks associated with construction activities occurring at the Fillmore Street underpass, particularly in removing the pump station and filling the underpass.

The pump station is an integral part of the north retaining wall and the Fillmore Street bridge abutment. The pump station was likely designed to support earth pressures that are ultimately transferred to the abutment. In order to remove the structure, temporary shoring would be required. The shoring would have to retain about 37 feet of soil, requiring substantial lateral bracing. Because the structure is located within the westbound service road and in Fillmore Street, considerable disruption to traffic would occur. In lieu of removal, it may be more feasible to fill the pump station in place and disconnect and decommission it. Minimization measures specific to removing or filling the Fillmore Street underpass are included to reduce such effects.

4.7.4.4 | OPERATIONAL EFFECTS

Each build alternative would include the following components subject to strong ground shaking and potential liquefaction-induced ground settlement:

- New paving and rehabilitation or resurfacing of existing pavement throughout the Geary corridor;
- pedestrian crossing bulbs;
- BRT (Bus Rapid Transit) stations and associated amenities; and
- installation of streetlights and associated conduit trench replacement.

Soils in the Geary corridor appear to be suitable for proposed improvements identified in each of the build alternatives and the No Build Alternative. As discussed above, some of the proposed bus stations and other features of the build alternatives would be located within areas of potential liquefaction and/or areas with artificial fill. The foundations for new BRT stations would be approximately 5 feet deep. Design features to address very strong ground shaking, liquefaction, and settlement are discussed below in Section 4.7.5.

Overall, build alternative structures are limited to streetscape features that would bear relatively light loads; therefore, the risk of geologic hazards is low. The design of project features would meet seismic standards, and the incorporation of minimization measures discussed below would reduce any such risks further.

4.7.4.5 | COMPARATIVE EFFECTS OF ALTERNATIVES

A demonstrated in the preceding subsections, all project alternatives, including the No Build Alternative, would be subject to potential slope instability effects, area-wide potential for ground shaking, and site specific liquefaction, during construction. As all project alternatives are located within the same geologic setting, differences between the construction-period and operational impacts of all project alternatives would be marginal.

4.7.5 | Avoidance, Minimization, and/or Mitigation Measures

With adherence to the measures below, the build alternatives would not result in any adverse geological or seismic-related effects. The designs shall be reviewed by a geotechnical consultant. The recommendations from the geotechnical consultant shall be incorporated into the final approved designs and shall address geologic/seismic stability of the project during construction and operation. The geotechnical recommendations may include the following:

4.7.5.1 | CONSTRUCTION MEASURES

MIN-GE-C1. Shoring will be typically required for all cuts deeper than five feet. Shoring design of open excavations must consider the potential surcharge load from neighboring structures. Furthermore, the potential for lateral movement of excavation walls as a result of earthquake-related surcharge load from nearby structures must also be assessed. The following shoring and slope stability BMPs will be implemented during construction:

- Heavy construction equipment, building materials, excavated soil, and vehicle traffic shall be kept away from the edge of excavations, generally a distance equal to or greater than the depth of the excavation.
- In the event of wet weather, storm runoff shall be prevented from entering the excavation. Excavation sidewalls can be covered with plastic sheeting, and berms can be placed around the perimeter of the excavated areas.
- Sidewalks, slabs, pavement, and utilities adjacent to proposed excavations shall be adequately supported during construction.

4.7.5.2 | OPERATIONAL MEASURES

MIN-GE-1: A geotechnical consultant shall review the design of the build alternatives and offer recommendations best suited to the build alternative carried forward. Any recommendations provided by the geotechnical consultant shall be incorporated into the final plans, and are likely to include the following:

> **MIN-GE-1a**. For lightly loaded structures such as bus stops, canopies, and walls, incorporate geotechnical and/or structural methods to mitigate the effects of liquefaction on the foundations during final design. The geotechnical mitigation methods may range from recompaction of the upper material to provision of a mechanically stabilized earth (MSE) foundation system. The structural mitigation methods may range from planning for repairs/maintenance after a seismic event to supporting the improvements on mat foundations or interconnected beam foundations to tolerate the anticipated seismic settlement without collapse.

MIN-GE-1b. Fill soils shall be overexcavated and replaced with engineered fill as needed.

MIN-GE-1c. Deeper foundations shall be designed for station platforms and canopies located in areas of fill or areas mapped as liquefaction areas, as needed.

Should Alternatives 3 or 3-Consolidated be selected, minimization measures specific to filling the Fillmore Street underpass include all of the following:

MIN-GE-2. Fill material shall have characteristics similar to the original ground (dune sand), especially comparable unit weight and permeability. With such material, settlement under the fill weight would be "recompression" and groundwater flow would be similar (except for the effects of the retaining wall and roadway slab). Considering the area is generally underlain by sand, the settlements would be "immediate."

MIN-GE-3. If the existing pump station will remain in place, it shall be filled with concrete or a cementitious material, such as controlled density fill (CDF), and a portion of the structure shall be removed to a depth that will not impede future utilities in the service road. Once the pump stops operating, the groundwater will start to rise. The construction sequencing needs to consider the higher groundwater condition, including potential uplift pressure on the bottom of the pump station, roadway slab, etc. Continued, temporary pumping might be required. The special drainage structure behind the south retaining wall/abutment shall be similarly filled.

MIN-GE-4. The large collector pipes for the existing subsurface drainage facilities shall be filled with slurry.