4.10 GEOLOGY, SOILS, AND SEISMICITY

4.10.1 INTRODUCTION

This section describes the geology of the SVRTC and the susceptibility of site soils to seismically induced hazards. Faults in the corridor and past and probable future activity are addressed. Information presented in this section summarizes the *Geotechnical Exploration Findings and Recommendations Report* (Earth Tech, Inc. 2003).

4.10.2 EXISTING CONDITIONS

This section describes the existing geologic and seismic setting of the SVRTC study area.

4.10.2.1 Geology and Soils

The SVRTC is located in the Santa Clara Valley, a northwest trending valley separated by intervening ranges within the Coast Ranges geomorphic province of Northern California. The Santa Clara Valley is an alluvial basin located between the Santa Cruz Mountains to the southwest and the Diablo Range to the northeast. The valley is covered by alluvial fan, levee, and active stream channel deposits with marine estuary deposits along the Bay margins. These unconsolidated deposits cover Tertiary through Cretaceous age bedrock.

The entire SVRTC lies on alluvial deposits that are underlain, at depths much greater than would be encountered during construction of either the Baseline or the BART Alternative, by Tertiary age and upper Cretaceous age marine sedimentary rocks and Cretaceous age Franciscan Complex bedrock. These older rocks appear at the surface in the ranges southwest and northeast of the SVRTC. The alluvium has been described as Holocene age alluvial fan deposits, fine-grained Holocene alluvial fan deposits, and Holocene alluvial fan levee deposits. These alluvial fan deposits consist of sand, gravel, silt, and clay. Fine-grained alluvial fan deposits occur on the flatter distal portions of fans and consist primarily of silt and clay-rich sediments with interbedded lobes of coarser sand and occasional gravel. The Holocene alluvial fan levee deposits consist of silt, sand, and clay.

Near the north end of the BART Alternative and the area proposed for new aerial bus connectors, the alluvial fan deposits grade into Holocene alluvial fan-estuarine complex deposits and Holocene Bay Mud. Holocene alluvial fan-estuarine complex deposits form where the distal zone of the fan and basin environments transition to the estuarine environment at the edge of San Francisco Bay between the Guadalupe River and Coyote Creek. These deposits are transitional from sand, silt, and clay of the alluvial environment to Bay Mud.

Based on the current profile of the tunnel alignment, the eastern portion of the tunnel (east of the Market Street Station) will likely encounter predominately fine-grained silts and clays of medium to stiff consistency, with occasional soft deposits. From Market Street Station and proceeding west, some granular deposits of sand and gravel to silty sand and clayey sand interbedded in fine grained silts and clays are expected.

Artificial fill may be present over any of these Holocene age deposits along the SVRTC. Areas within the SVRTC with other soil conditions such as expandable or compressible soils will be identified by detailed geotechnical studies during the design phase of the project.

4.10.2.2 Seismicity

The SVRTC lies between the active San Andreas Fault to the west and the Hayward and Calaveras faults to the east. It is located within one of the most seismically active regions in the world, the San Andreas

Fault system, which marks the tectonic boundary between the Pacific and North American plates. Motion across the plate boundary is accommodated on a number of faults. Table 4.10-1 provides a listing of the faults in the region along with information on their location and past and probable future seismic activity. Figure 4.10-1 shows the location of regional active faults relative to the SVRTC.

The Hayward and the San Andreas faults have the highest slip rates and are the most active of all the faults in the Bay Area. The Hayward Fault is the closest active fault to the SVRTC and was the source of an 1868 magnitude 7 earthquake. The San Andreas Fault, the largest active fault in California, was the source of the San Francisco 1906 magnitude 7.9 earthquake and the 1989 magnitude 7.1 (Loma Prieta) earthquake. The Calaveras Fault, a main component of the San Andreas System, recorded earthquakes of magnitude 5.9 in 1979 and 6.2 in 1984.

Other important earthquake sources that are capable of producing large magnitude earthquakes are the San Gregorio, Rodgers Creek, Hayward Southeast Extension, Sargent, Concord-Green Valley, Ortigalita, and Greenville Fault zones along with the faults of the Foothills thrust belt. All of these faults lie within 40 miles of the BART Alternative station areas and some lie as close as 0.6 miles from project facilities (for example, Hayward Fault at Warm Springs, which is close to the aerial bus connectors proposed under the Baseline Alternative).

About half of the SVRTC is within areas of high to very high liquefaction susceptibility and about half of the corridor is within areas of moderate susceptibility. Figure 4.10-2 shows the liquefaction susceptibility of different areas in and near the SVRTC. The impact of liquefaction on the tunnel will be negligible. However, in the event of a strong earthquake, some liquefaction of granular layers below the tunnel is anticipated at four locations along the alignment, which could result in settlements of about ½ to 1½ inches.

The potential for liquefaction at locations where the tunnel crosses below Coyote Creek, Guadalupe River, and Los Gatos Creek was evaluated and documented in the *Geotechnical Exploration Findings and Recommendations Report* (Earth Tech, Inc. 2003). The potential for lateral spreading and lurching at Coyote Creek appears to be low due to the soil profile, whereas at Guadalupe River and Los Gatos Creek there is a potential for liquefaction primarily within the upper 20 feet of the soil profile. However, while lurching or lateral spreading of the channel banks is conceivable, it is unlikely, as the crown of the tunnel extends approximately 30 feet below channel bottom. Therefore, lurching or lateral spreading is not anticipated to impact the tunnel at these locations.

4.10.3 IMPACT ASSESSMENT AND MITIGATION MEASURES

This section focuses on the potential for geologic or seismicity features of the SVRTC area to affect the proposed project, or for the project to increase the potential exposure of people to hazard from geologic or seismic risks. Geology, soils, and seismicity impacts related to construction can be found in Section 4.19.9.1, *Construction/Geology, Soils and Seismicity Impacts*.

4.10.3.1 Geology, Soils, and Seismicity Impacts

No-Action Alternative

Projects planned under the No-Action Alternative would undergo separate environmental review to define geologic, soils, and seismic impacts. (See Section 3.2.1.2 for a list of future projects under the No-Action Alternative.)

Table 4.10-1: Faults in the Vicinity of the Silicon Valley Rapid Transit Corridor		
Fault/Thrusts	**Location and Description**	**Seismic Activity**
Hayward Fault	Closest active fault to the corridor. Extends 100 km from the area of Mount Misery in San Jose to Point Pinole on San Pablo Bay.	Last major earthquake occurred in October 1868 and had a Richter magnitude of 7. Capable of generating maximum credible earthquake (MCE) of moment magnitude (Mw) 7.1 (Working Group on California Earthquake Probabilities [WGCEP] 1999).
Hayward Southeast Extension	Sequence of southwest–verging, reverse faults, located in the restraining left-step between the Calaveras and Hayward faults.	Capable of creating an MCE of M_w 6.4, with a recurrence interval of 220 years (Working Group on Northern California Earthquake Potential [WGNCEP] 1996).
Rodgers Creek Fault	44 km. long, northern continuation of Hayward Fault.	Most likely source of the next M_w 6.7 or larger earthquake in the Bay Area, with 32 percent probability of occurring in the time period 2000 to 2030 (WGCEP 1999).
Calaveras Fault	Main component of the San Andreas system, branching off the main San Andreas Fault south of Hollister, extending northwards for approximately 120 km and ending in the area of Danville.	Generated a number of moderate-size earthquakes in historic time, including the 1979 local magnitude (M_L) 5.9 Coyote Lake and 1984 M_L 6.2 Morgan Hill events. WGCEP (1999) suggests that rupture of the entire fault would generate an MCE of M_w 7.2.
Sargent Fault	Northwest-striking, northeast-verging, 56km-long reverse-oblique fault zone that intersects the San Andreas Fault to the north near Lake Elsman, and the Calaveras Fault to the south beneath the southern Santa Clara Valley near Hollister.	Capable of generating an MCE of M_w 6.8 (WGNCEP, 1996).
Foothills Thrust Belt	Sequence of southwest dipping thrusts, bounded by the San Andreas Fault to the west.	Active faults, capable of generating MCE of M_w 6.8 (Fenton and Hitchcock 2001).
San Andreas Fault	Extends from the Gulf of California, Mexico, to Point Delgado on the Mendocino Coast in Northern California, a total distance of 1,200 km.	Largest active fault in California, responsible for the largest earthquake in California, the 1906 M_w 7.9 San Francisco earthquake. Assigned a recurrence interval of 361 years to a M_w 7.9 1906-type event (WGCEP 1999).
San Gregorio Fault	Principal active fault west of the San Andreas Fault in the coastal region of Central California.	WGCEP (1999) assigns an MCE of M_w 7.5 for an earthquake rupturing the entire length of the fault.
Monterey Bay- Tularcitos Fault	Zone of strike-slip faulting comprising the Monterey Bay, Navy, and Tularcitos faults.	WGCEP (1999) assigns an effective recurrence of 2,600 years for an MCE of M_w 7.1 on this fault.
Concord-Green Valley Fault	Continuation of the Concord Fault on the northern side, the Green Valley Fault is a northwest-striking right-lateral strike-slip fault of the San Andreas system.	WGCEP (1999) assigns an MCE of M_w 6.8 for an earthquake rupturing the entire length of the fault.

continued

Table 4.10-1: Faults in the Vicinity of the Silicon Valley Rapid Transit Corridor

Fault/Thrusts	Location and Description	Seismic Activity
West Napa Fault	North-northwest-striking right lateral strike-slip fault located along the western side of Napa Valley, from south of Napa to Yountville, a distance of approximately 25km.	Rupture of the entire fault would generate an MCE of M_w 6.5 (WGNCEP 1996) with a recurrence interval of 700 years.
Greenville Fault	North-northwest to northwest-striking strike-slip fault of the San Andreas system in the northern Diablo Range, extending from Bear Valley to just north of Livermore Valley.	WGCEP (1999) assigned a maximum earthquake of M_w 7.2.
Ortigalita Fault	North-northwest-striking, right-lateral strike-slip fault, 66 km long, located in the southern Diablo Range.	The MCE is M_w 6.9, with an effective recurrence of 1,100 years (WGNCEP 1996).
Coast Range-Sierran Block Boundary (CRSB)	Complex zone of thrust faulting that marks the boundary between the Coast Range block and the Sierran basement rocks that are concealed beneath the Great Valley sedimentary rocks of the Sacramento and San Joaquin Valleys.	The closest segments of the CRSB are capable of generating an MCE of M_w 6.6 to 6.7 (WGNCEP 1996).
Sacramento Delta Faults	Consists of a number of Quaternary active thrust faults (Roe Island Thrust, Potrero Hills Thrust Fault, Pittsburg-Kirby Hills Fault, and the Midland Fault) beneath a series of right-stepping en echelon anticlines to the north of Mount Diablo.	The M_w of MCE and slip rates for these faults are as follows (Unruh 1999): Roe Island Thrust Fault – MCE of M_w 5.5 to 6.0; Potrero Hills Thrust Fault – MCE of M_w 6.0; Pittsburg-Kirby Hills Fault – MCE of M_w 6.3; Midland Fault – MCE of M_w 6.3.
Mount Diablo Thrust Fault	Northeast dipping, southwest propagating thrust fault beneath the Mount Diablo anticline.	Capable of generating an MCE of M_w 6.8 (Unruh 1995).
Los Medanos Thrust	Underlies the asymmetric, southwest-tilted Los Medanos and Concord anticlines.	The MCE for the thrust ranges from M_w 5.8 to 6.3 (Unruh 1997).
East Bay Thrust Domains	Region of elevated topography between the Hayward and the Calaveras faults. Consists of three domains: Western East Bay Hills, Southern East Bay Hills, and Northern East Bay Hills domains.	The M_w of MCE these domains can generate are as follows: Western East Bay Hills Domain: capable of generating MCE of M_w 6 (Wakabayashi and Sawyer 1998); Southern East Bay Hills Domain: capable of generating earthquakes of M_w 6.3 to 6.5; Northern East Bay Hills Domain: capable of generating earthquakes of M_w 6.3 to 6.8 (Geomatrix Consultants 1998).
Quien Sabe Fault	Right-lateral strike-slip fault, 22 km long, located to the east of Tres Piños.	Capable of generating an MCE of M_w 6.4 (WGNCEP 1996).

Source: URS Corporation, 2002.

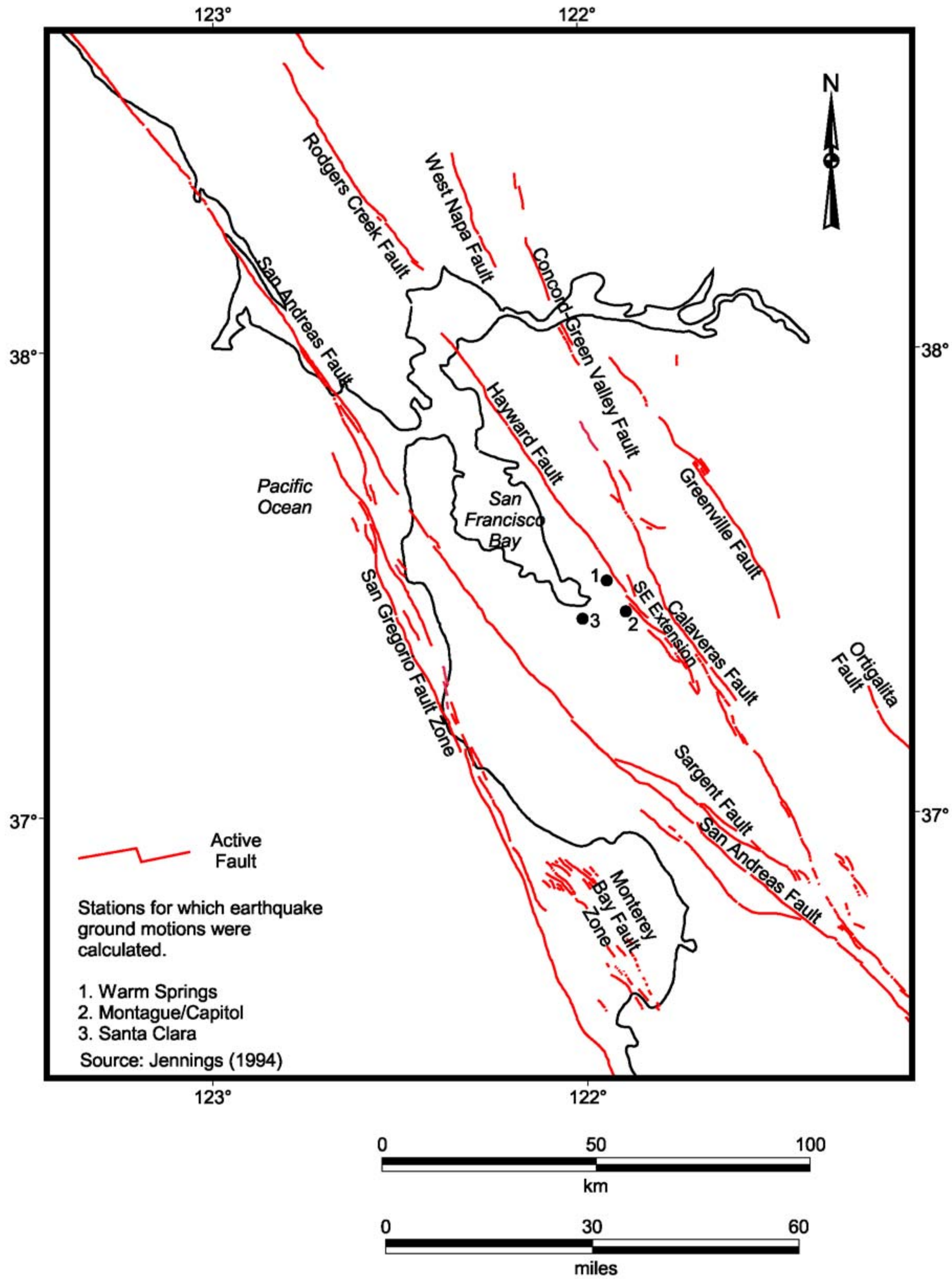

Figure 4.10-1: Location of Regional Active Faults Relative to the SVRTC

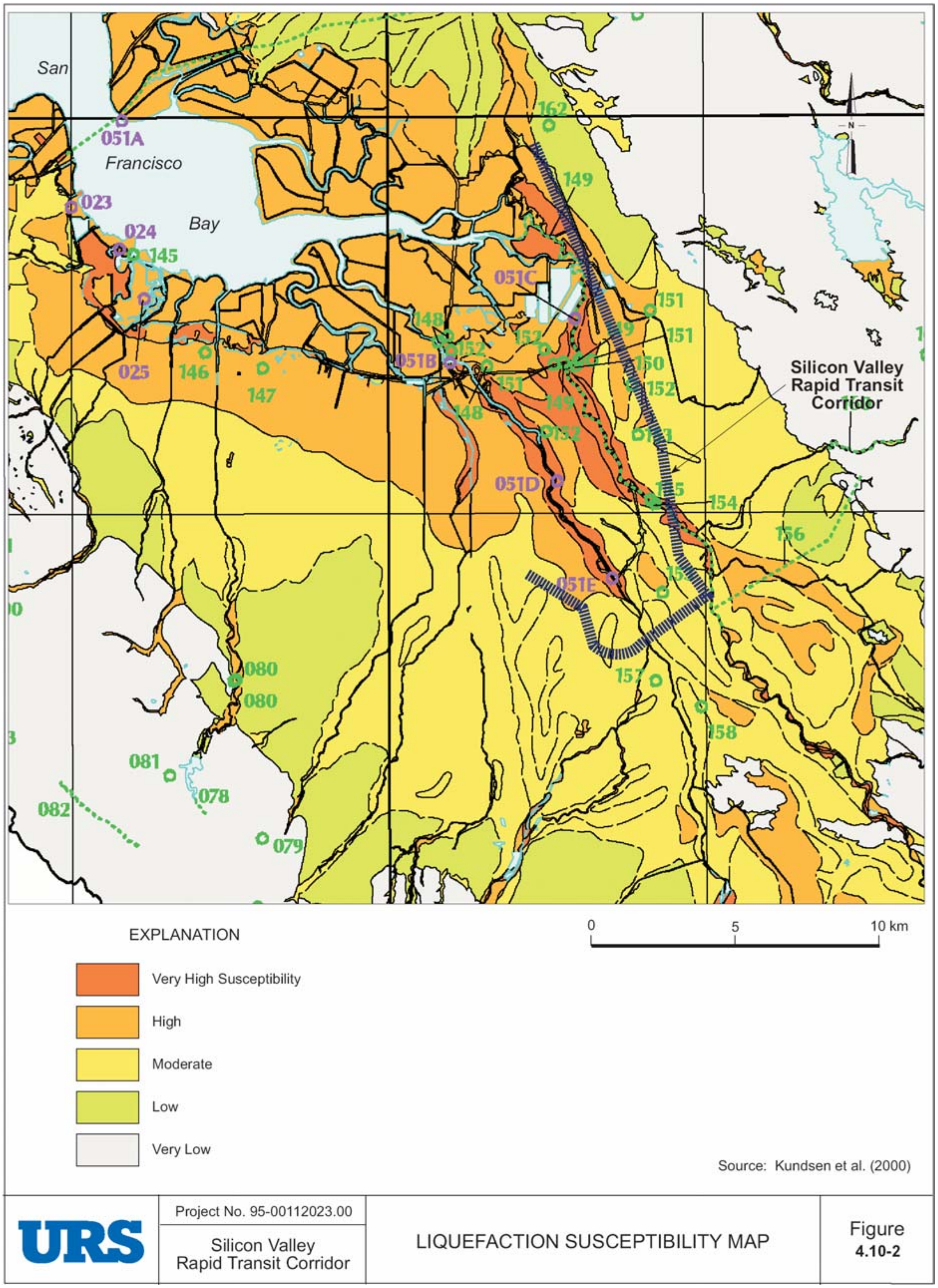

Figure 4.10-2: Liquefaction Susceptibility Map

Baseline and BART Extension Alternatives

The potential geologic and seismic impacts on the Baseline and BART alternatives include fault rupture, strong ground shaking, liquefaction, lateral spreading, ground lurching, cracking, warping, and settlement.

There are no known active faults crossing, or in sufficiently close proximity to, the SVRTC project alignment; therefore, the potential for ground rupture along the alignment due to faulting is considered very low. The closest active fault is the Hayward Fault, approximately 0.6 miles away from the planned BART Warm Springs Station. The proximity of this fault and other nearby active faults, which are capable of generating large magnitude earthquakes, means that strong ground shaking will probably be the major geologic hazard to both the Baseline and BART alternatives. Strong ground shaking may directly cause damage to project structures and may also cause liquefaction, as about half of the SVRTC is within areas of high to very high liquefaction susceptibility and about half of the corridor is with in areas of moderate susceptibility, as shown in Figure 4.10-2. Strong ground shaking may also cause related secondary seismic hazards such as lateral spreading, ground lurching, cracking, warping, and settlement.

The MOS scenarios include the same alignment as the full-build BART Alternative. Therefore, the potential for ground shaking and related secondary seismic hazards are the same as for the full-build BART Alternative.

4.10.3.2 Design Requirements and Best Management Practices

Baseline and BART Alternatives

Project structures associated with the Baseline or BART alternative, as well as the MOS scenarios, will be designed in accordance with current seismic design standards as found in the California Uniform Building Code (CUBC) and other applicable building codes. All structures for the BART Alternative and MOS scenarios will also be built in compliance with BART's guidelines and criteria of the BART Facilities Standards to reduce potential damage and facilitate repair in the event of seismically induced ground failures. These measures will reduce the potential exposure of people to hazard from geologic or seismic risks.

The extent of other hazards including seismically induced liquefaction will be minimized by geotechnical studies during the design phase of the project. These studies will include a detailed investigation to identify areas of possible liquefaction due to strong ground shaking. Site improvement measures to reduce liquefaction potential and engineering design to resist movement due to liquefaction will be identified and may include in-situ densification such as vibroflotation, stone columns, or dynamic compaction.

4.10.3.3 Mitigation Measures

No-Action Alternative

Projects planned under the No-Action Alternative would undergo separate environmental review to define geologic, soils, and seismic impacts and to determine appropriate mitigation measures.

Baseline and BART Alternatives

The results of the preliminary geologic hazards evaluation of the Baseline and BART alternatives, as well as the MOS scenarios, indicate that there are no substantial geologic hazard impacts with the implementation of design requirements and best management practices. Therefore, no mitigation measures are required.

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