

4.7 GEOLOGY AND SEISMICITY

This section describes the regional and local geology in the study area and the susceptibility of site soils to seismically induced hazards. The study area includes the entire 16.1-mile alignment from the Warm Springs BART Station to the planned Santa Clara BART Station and runs through portions of the cities of Fremont, Milpitas, San Jose, and Santa Clara. Regional and local geologic faults and past and probable future seismic activity are addressed.

4.7.1 METHODOLOGY FOR IDENTIFYING EXISTING CONDITIONS

Information about the geologic/seismic conditions and liquefaction potential in the study area is based on the *Geotechnical Exploration Findings and Recommendations Report* (Earth Tech, Inc., 2003) as well as additional geotechnical and seismic reports prepared during the Conceptual and Preliminary Engineering design phases of the alternatives. These are listed in Chapter 14 of this EIS. The studies evaluated general subsurface conditions and seismicity, engineering properties related to soil conditions, and provided preliminary geotechnical recommendations for the BEP and SVRTP alternatives.

To evaluate the geologic conditions, geologic publications and consultants' reports were reviewed and subsurface exploration was conducted. The sub-surface exploration consisted of 141 geotechnical borings and 23 cone penetrometer tests (CPTs)¹ that were drilled or pushed during Preliminary Engineering for the 9.9 miles of the BEP Alternative (from the planned BART Warm Springs Station to the east tunnel portal). The sampling depths generally ranged from 25 to 100 feet below ground surface (bgs). For the tunnel alignment (SVRTP Alternative), 76 geotechnical borings were drilled. Of these, 20 were drilled at three proposed underground stations (Alum Rock, Downtown San Jose, and Diridon/Arena), 53 along the tunnel alignment, and 3 at the portals. In addition, 146 CPTs were performed along the tunnel alignment, including 38 CPTs at the three proposed underground stations. The sampling depths for the borings and CPTs ranged from near surface to up to approximately 220 feet bgs. For the yard and shops facility, 32 geotechnical borings and 35 CPTs were drilled or pushed. The sampling depths for the borings and CPTs ranged from 20 to 81 feet bgs.

4.7.2 GEOLOGY AND SOILS

The geologic study area 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

¹ Cone Penetrometer Tests (CPT) are compression tests using a hammer-like device to determine the compaction properties of soil.

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 study area is located in an area of the valley that is very level and there are no large steep slopes. Soils in the study area are depicted on Figure 4.7-1.

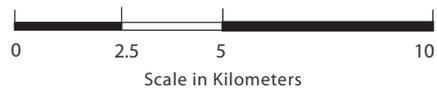
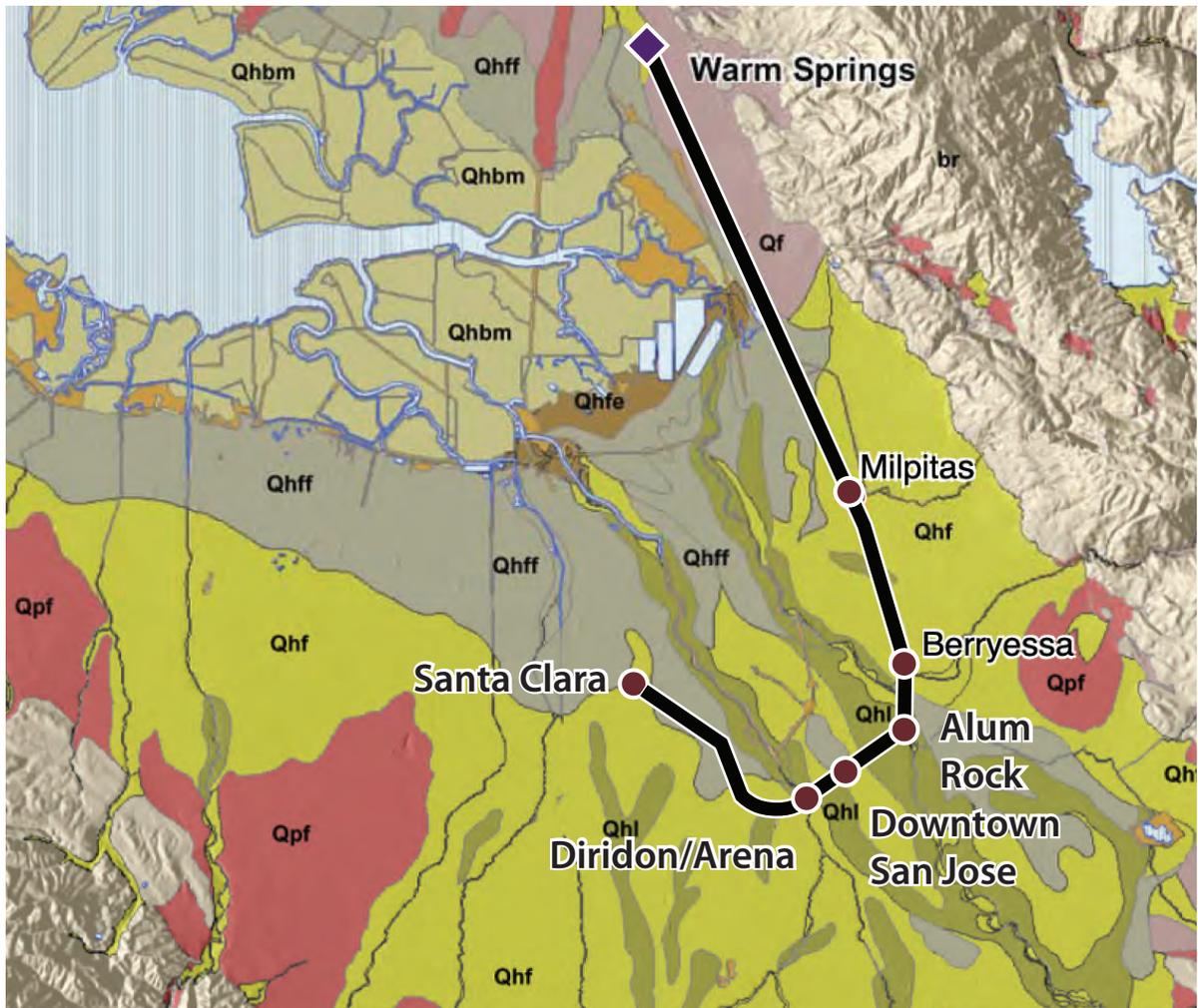
The study area lies on alluvial deposits are underlain by Tertiary age and upper Cretaceous age marine sedimentary rocks and Cretaceous age Franciscan Complex bedrock at depths much greater than would be encountered during construction of the BEP and SVRTP alternatives. The alluvium has been described as Holocene age alluvial fan deposits, fine-grained Holocene alluvial fan deposits, and Holocene alluvial fan levee deposits. 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. Artificial fill may be present over any of the Holocene age deposits in the study area. Areas within the study area with other soil conditions such as expandable or compressible soils will be identified by detailed geotechnical studies during the alternatives' design phase.

Starting at the Warm Springs Station in the City of Fremont, the alluvial fan deposits begin as Latest Pleistocene to Holocene alluvial fan-estuarine complex deposits and grade into Holocene Bay Mud as the study area travels south. 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.

After crossing the Guadalupe River and Coyote Creek, soils in the study area go from Holocene Bay Mud to fine-grained Holocene alluvial fan deposits. Before reaching the City of Milpitas, the soils transition to Holocene alluvial fan deposits. From Milpitas to Berryessa Station, study area soils are consistently Holocene alluvial fan deposits. Between Berryessa Station and Alum Rock Station soils turn into a mixture of fine-grained Holocene alluvial fan deposits and Holocene alluvial fan levee deposits. At Alum Rock Station, the SVRTC turns west and heads toward San Jose. Soils encountered between Alum Rock and Diridon/Arena Stations mainly consist of Holocene alluvial fan levee deposits and Holocene alluvial fan deposits, with some fine-grained Holocene alluvial fan deposits. After turning north at Diridon/Arena Station, study area soils consist of Holocene alluvial fan deposits. This remains the dominant soil type through the study area terminus at Santa Clara Station.

4.7.3 SEISMICITY

There is no known active fault crossing the 16.1 mile alignment. 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



Legend:

MODERN

afbm; Artificial fill over San Francisco Bay Mud

HOLOCENE

- Qhbm; Holocene San Francisco Bay Mud
- Qhfe; Holocene alluvial fan-estuarine complex deposit
- Qhff; Fine-grained Holocene alluvial fan deposits
- Qhf; Holocene alluvial fan deposits
- Qhl; Holocene alluvial fan levee deposits

LATEST PLEISTOCENE TO HOLOCENE

- Qf; Latest Pleistocene to Holocene alluvial fan deposits
- Qp; Latest Pleistocene alluvial fan deposits

PRE-PLEISTOCENE

- br; bedrock

BEP/SVRTP ALTERNATIVE STRUCTURES

- Proposed BART Alignment
- Approved BART Station
- Proposed BART Station

Source: Knudsen et al., 2000; URSS, 2003; VTA, 2008.

Figure 4.7-1: Geology of the Santa Clara Valley

Pacific and North American plates. Motion across the plate boundary is accommodated on a number of faults. Table 4.7-1 provides a listing of the faults in the region along with information on their location and past and probable future seismic activity, including 2002 data from the Working Group on California Earthquake Probabilities. Figure 4.7-2 shows the location of regional active faults relative to the BEP and SVRTP alternatives' alignments.

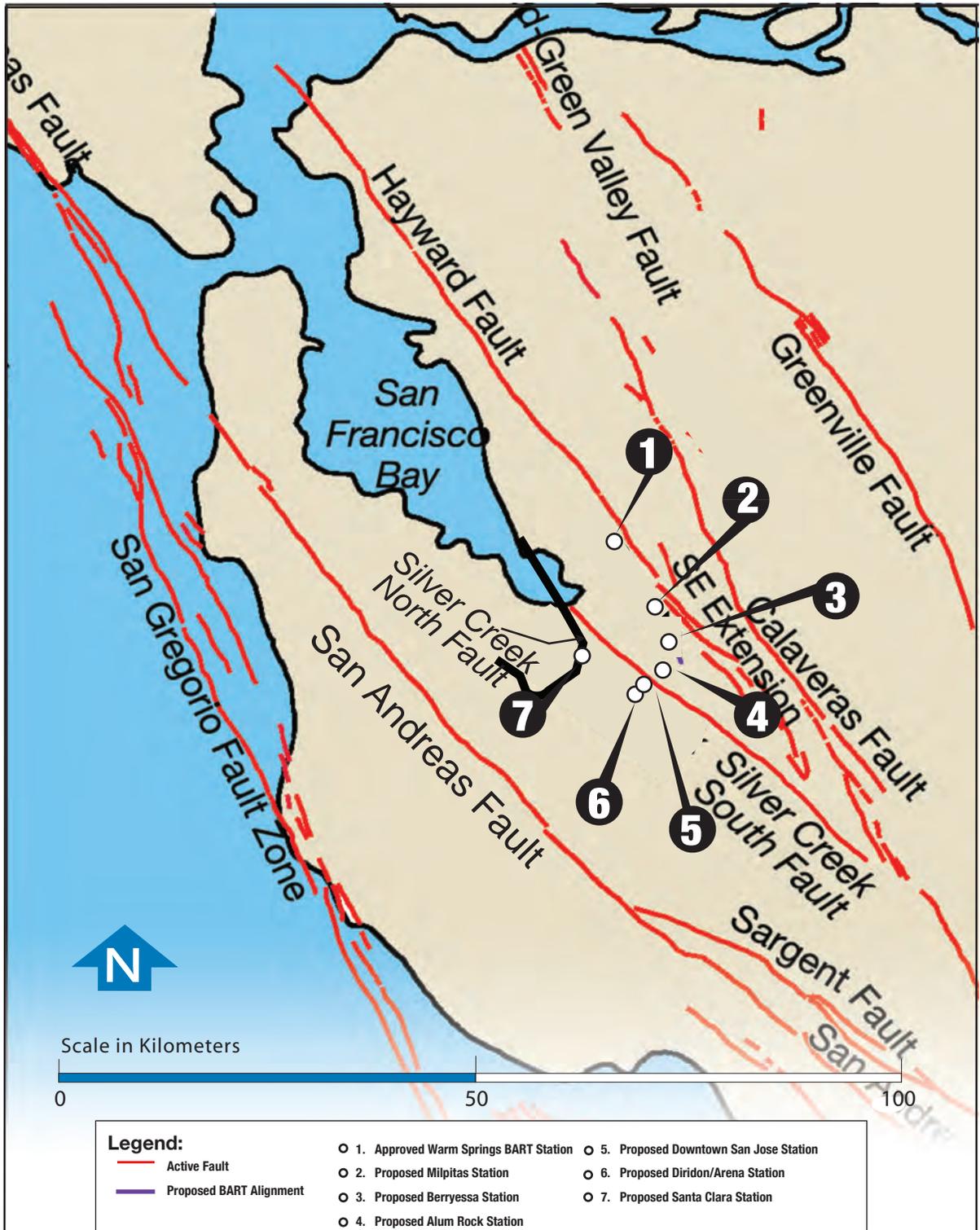
The Hayward and San Andreas faults have the highest slip rates and are the most active of all the faults in the Bay Area. The Hayward Fault is the closest active fault to the alternatives' alignments, at a distance of 1.3 kilometers, and was the source of an 1868 magnitude 7 earthquake. The San Andreas 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 and is 16.9 kilometers from the SVRTC. The Calaveras Fault, a main component of the San Andreas System, recorded earthquakes of magnitude 5.9 in 1979 and 6.2 in 1984 and is approximately 5.2 kilometers from the alternatives' alignments.

Other faults that are capable of producing large magnitude earthquakes are the San Gregorio, Rodgers Creek, Hayward Southeast Extension, Sargent, Concord-Green Valley, Ortigalita, Silver Creek, and Greenville Fault zones along with the faults of the Foothills thrust belt. All of these faults lie within 40 miles of the SVRTC. The closest distance to an active fault is the south end of the Hayward Fault at approximately 0.6 miles from the northern end of the SVRTC.

4.7.4 LIQUEFACTION

The term liquefaction describes a phenomenon by which saturated soils temporarily lose shear strength due to strong ground motions, causing them to liquefy. This can cause structures built on or above these soils to experience bearing capacity failure and collapse. Factors known to influence liquefaction include soil type, relative density, grain size, depth to groundwater, age of soil, and the intensity and duration of ground shaking. Soils most susceptible to liquefaction are Holocene age, loose, coarse-grained poorly graded sands and low plasticity silts below the water table.

The study area falls partially or completely within liquefaction hazard areas on three Seismic Hazard Zone maps (Milpitas Seismic Hazard Quadrangle, October 2004; San Jose East Quadrangle, January 2001; and San Jose West Quadrangle, February 2002). Based on preliminary geotechnical investigations conducted for the study area in 2003, approximately 30 percent of the study area is within areas of low liquefaction susceptibility, 50 percent is within areas of moderate susceptibility, and the remaining 20 percent is within areas of high susceptibility. Thus, the majority of the SVRTC is identified as being located in a liquefaction hazard zone. The California Geologic Survey has identified liquefaction as being a potential seismic hazard at locations where the tunnel crosses below Coyote Creek, Guadalupe River, and Los



Source: Jennings, 1994; VTA, 2008.

Figure 4.7-2: Location of Regional Active Faults

Table 4.7-1: Faults in the Vicinity of the Study Area

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 a maximum credible earthquake (MCE) of moment magnitude (Mw) 7.1 (Working Group on California Earthquake Probabilities [WGCEP], 2002).
Hayward Southeast Extension	Sequence of southwest-verging, reverse faults, located in the restraining left-step between the Calaveras and Hayward faults.	Capable of creating a MCE of Mw 6.7, with a recurrence interval of 292 years (WGCEP, 2002).
Rodgers Creek Fault	44 km. long, northern continuation of Hayward Fault.	Most likely source of the next Mw 6.7 or larger earthquake in the Bay Area, with 27 percent probability of occurring in the time period 2002 to 2031 (WGCEP, 2002).
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 (ML) 5.9 Coyote Lake and 1984 ML 6.2 Morgan Hill events. WGCEP (2002) suggests that the probability of one earthquake with mean magnitude from M 5.8 to M 6.9 occurring in 2002-2031 is 59 percent.
Foothills Thrust Belt	Sequence of southwest dipping thrusts, bounded by the San Andreas Fault to the west. From north to south, the main mapped thrust faults include the Stanford, Pulgas, Monte Vista, Shannon, Berrocal, Sierra Azul, and Sargent faults.	Active faults, capable of generating a MCE of Mw 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 Mw 7.9 San Francisco earthquake. Assigned a recurrence interval of 378 years to a Mw 7.9 1906-type event (WGCEP, 2002).
San Gregorio Fault	Principal active fault west of the San Andreas Fault in the coastal region of Central California.	WGCEP (2002) assigns an MCE of Mw 7.4 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.	The largest historical earthquakes that have occurred in this zone are Mw 5.8 earthquakes on February 1870 and March 1910. No other historical earthquakes of magnitude greater than 5.0 have occurred in the Monterey Bays source area.
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 (2002) assigns an MCE of Mw 6.7 with a recurrence interval of 580 years for an earthquake rupturing the entire length of the fault.

Table 4.7-1: Faults in the Vicinity of the Study Area (continued)

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 a MCE of Mw 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 (2002) assigned a maximum earthquake of Mw 6.9.
Ortogonalita Fault	North-northwest-striking, right-lateral strike-slip fault, 66 km long, located in the southern Diablo Range.	The MCE is Mw 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 Coastal Range-Sierran Block Boundary are capable of generating a MCE of Mw 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 Mw of MCE and slip rates for these faults are as follows: (Unruh, 1999) Roe Island Thrust Fault – MCE of Mw 5.5 to 6.0; Potrero Hills Thrust Fault – MCE of Mw 6.0; Pittsburg-Kirby Hills Fault – MCE of Mw 6.3; Midland Fault – MCE of Mw 6.3.
Mount Diablo Thrust Fault	Northeast dipping, southwest propagating thrust fault beneath the Mount Diablo anticline.	Capable of generating a MCE of Mw 6.8 (Unruh, 1995)
Los Medanos Thrust	Underlies the asymmetric, southwest-tilted Los Medanos and Concord anticlines.	The MCE for the thrust ranges from Mw 5.8 to 6.3 (Unruh, 1997)
East Bay Thrust Domains	Region of elevated topography between the Hayward and Calaveras faults, Consists of three domains: Western East Bay Hills, Southern East Bay Hills, Northern East Bay Hills domains.	The Mw of MCE these domains can generate are as follows: Western East Bay Hills Domain – capable of generating MCE of Mw 6 (Wakabayashi and Sawyer, 1998); Southern East Bay Hills Domain – capable of generative earthquakes of Mw 6.3 to 6.5; Northern East Bay Hills Domain – capable of generating earthquakes of Mw 6.3 to 6.8 (Geomatrix Consultants, 1998).

Table 4.7-1: Faults in the Vicinity of the Study Area (continued)

Fault/Thrusts	Location and Description	Seismic Activity
Quien Sabe Fault	Right-lateral strike-slip fault, 22 km long, located to the east of Tres Piños.	Capable of generating a MCE of Mw 6.4 (WGNCEP, 1996).
Silver Creek Fault	Generally a north-northwest trending oblique-reverse-slip fault that extends over a distance of about 50 to 70 km, subparallel to and west of the Hayward and Calaveras fault zone (Fenton and Hitchcock, 2001). Southern reach is exposed while northern reach is buried beneath undisturbed Quaternary sediments. (Geomatrix, 2004; HMM/Bechtel, 2005).	Maximum magnitude distribution for the faults is in the range of 6.3 to 6.9 (HMM/Bechtel, 2005). The potential for fault rupture along northern reach negligible. Only the northern reach is located in the SVRTC.

Source: URS Corporation, 2002, Working Group on Northern California Earthquake Potential (WGNCEP) 1996, Working Group on California Earthquake Probabilities (WGCEP) 2002, HMM/Bechtel 2005; Geomatrix Consultants 2004; Kleinfelder, Inc. 2006.

Gatos Creek. This is based on the shallow depth to groundwater and Holocene-age soils that are present in the study area. Figure 4.7-3 shows the liquefaction susceptibility of different areas in and near the study area.

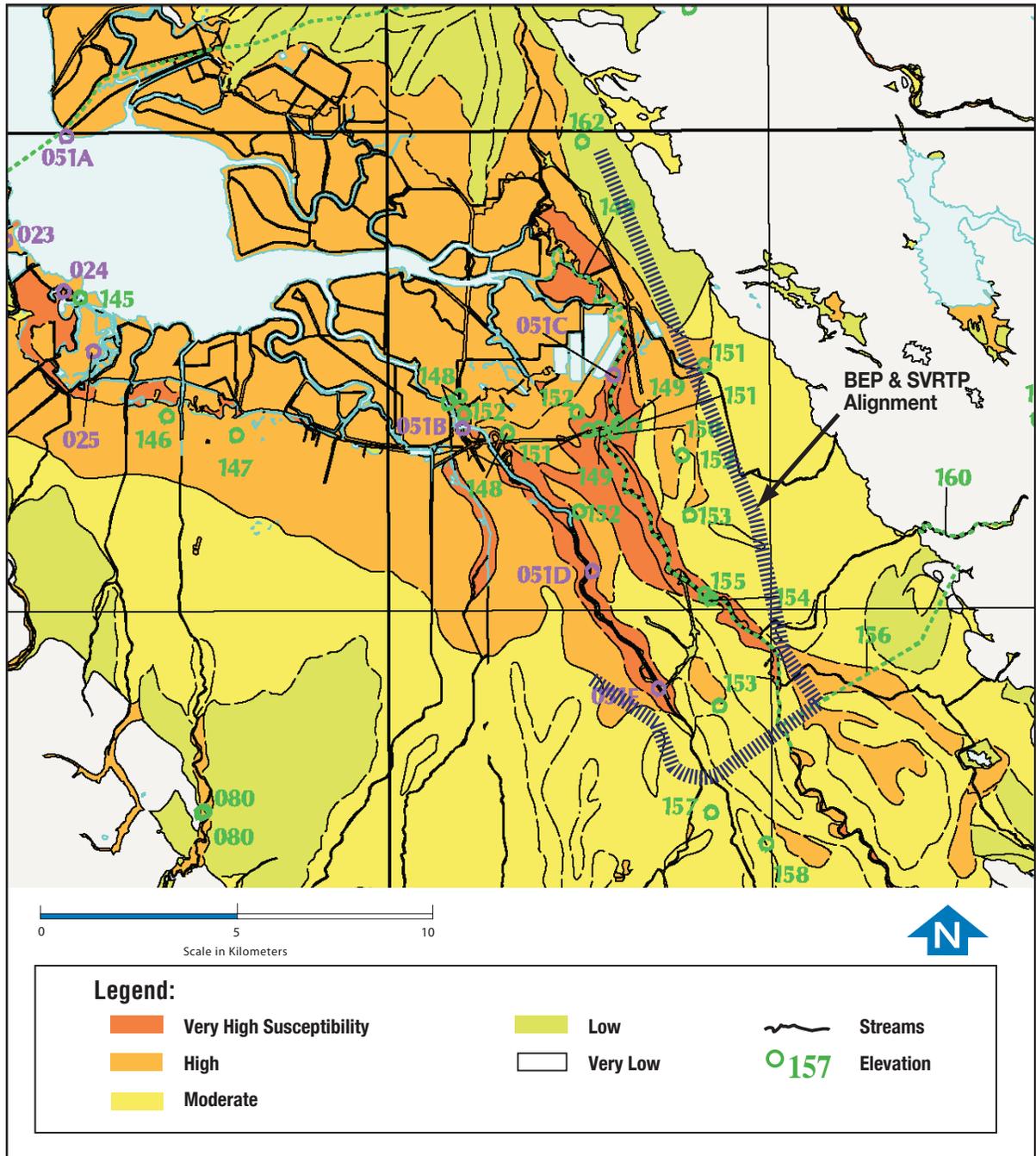
As the ground surface is relatively flat along the SVRTC, and is typically not adjacent to large open cuts or free faces, the potential for flow slide failures or lateral spreads is considered low. As such, the primary liquefaction hazard would be seismic induced settlement. Although a soil layer may or may not fully liquefy during an earthquake, it can still experience settlement. The BART Facilities Standards Design Criteria (Release 1.2 – Facility Design – Criteria – Structural – Foundations – section 2.1.1) limits the total settlement beneath structures to one inch. Table 4.7-2 lists locations that would exceed one inch of post-liquefaction settlement.

4.7.5 REGULATORY CONSIDERATIONS

Because much of California is seismically active, there are several state regulations that work together to identify seismic hazard zones and establish guidelines for site development and building in different seismic zones. Additionally, the general plans of the cities of Fremont, Milpitas, San Jose, and Santa Clara contain seismic safety policies.

Alquist-Priolo Earthquake Fault Zoning Act

The State of California maps Earthquake Fault Zones around active faults under the Alquist-Priolo Earthquake Fault Zoning Act. The purpose of the Act is to regulate development on or near fault traces to reduce the hazard of fault rupture and to prohibit the location of most structures intended for human occupancy across these traces. The Act only addresses the hazard of surface fault rupture and does not address other



Source: Kunden, et al. 2000.

Figure 4.7-3: Liquefaction Susceptibility Map

Table 4.7-2: Summary of Liquefaction Hazard Evaluation

Sampling Location	Stationing	Total Sampling Depth (ft)	Depth Range of Liquefaction (ft)	Depth to Base of Structure	Estimated Liquefaction Settlement (in)
B-80	358+40	56	10 to 13 13 to 17 27 to 32	4	3
B-81	361+50	61	15 to 17 28 to 32	10	1 to 2
B-82	363+90	61	13.5 to 18	14	1 to 2
B-91	383+50	51	30 to 32 35 to 38	22	1 to 2
CPT-92	384+10	100	26.3 to 29.8 34.7 to 35.2	19	1 to 2
B-96	389+50	46	7 to 15 (in backfill around siphon)	9	4
B-103	406+40	36	16 to 22	16	2 to 3
B-104	409+80	25	13.5 to 21.5	10	2 to 3
B-113	452+80	41	20.5 to 25.5	12	1 to 2
CPT-117	458+50	100	33.2 to 35.2 37.6 to 38.1	20	1 to 2
B-120	467+50	35.5	23 to 26 33 to 36	9	1 to 2
B-121	469+75	40.5	19 to 21 28 to 33	10	1 to 2
B-123	474+10	35.5	23.5 to 28.5	10	1 to 2
B-124	476+70	40	20 to 23 23 to 27	9	1 to 2
B-129	488+20	101.5	14 to 17 19 to 22	22	2 to 3
B-130	491+50	101.5	13 to 18 29.5 to 33 38 to 42.5 42.5 to 48	20	2 to 3
CPT-131	492+30	100	19.9 to 21.9 27.3 to 32.2 41.6 to 42.1 47.5 to 48	18	2 to 3
B-132	493+80	45	30 to 34 34 to 38 38 to 42 42 to 45	15	3 to 4

Table 4.7-2: Summary of Liquefaction Hazard Evaluation (continued)

Sampling Location	Stationing	Total Sampling Depth (ft)	Depth Range of Liquefaction (ft)	Depth to Base of Structure	Estimated Liquefaction Settlement (in)
B-133	497+50	31.5	15 to 17 21 to 26 26 to 31	6	3 to 4

Source: HNTP Corporation, Kleinfelder, December 2005

earthquake hazards such as earthquake-induced landslides, ground shaking, and liquefaction.

The BEP and SVRTP alternatives do not propose construction on an existing fault. Although the northernmost portion of the SVRTC is approximately 1.3 kilometers from the Hayward Fault Southeast Extension, this is not close enough to indicate a significant surface rupture hazard.

Seismic Hazards Mapping Act

The California Geological Survey addresses earthquake hazards other than surface fault rupture under the Seismic Hazards Mapping Act. Under the Act, various Seismic Hazard Zones are delineated on maps that identify areas potentially susceptible to earthquake-induced landslides and liquefaction. When a project falls in a Seismic Hazard Zone, the seismic hazard potential must be evaluated with site-specific studies and standard analysis procedures to identify ways to reduce hazards, as necessary.

California Building Code

The California Building Code is contained in the California Code of Regulations, Title 24, Part 2, which is a portion of the California Building Standards Code, and includes design and construction requirements related to fire, life safety, and structural safety. The California Building Code incorporates the Uniform Building Code (a widely adopted model building code in the United States) by reference, and includes necessary California amendments. These amendments include criteria for seismic design. The proposed BART extension would be built according to California Building Code specifications for seismic safety.

City of Milpitas General Plan Seismic and Safety Element

The City of Milpitas provides policies regarding geotechnical hazards in the General Plan Seismic and Safety Element. As noted below, these policies require compliance with state and local requirements.

Guiding Principle:

Minimize threat to life and property from seismic and geologic hazards.

Policy 5.a-I-1:

Require all projects within the Alquist-Priolo Special Studies Zone to have geologic investigations performed to determine the locations of active fault traces before structures for human occupancy are built.

Policy 5.a-I-2:

Require applications of all projects in the Hillside Area and the Special Studies Zone to be accompanied by geotechnical reports ensuring safety from seismic and geologic hazards.

Policy 5.a-I-3:

Require projects to comply with the guidelines prescribed in the City's *Geotechnical Hazards Evaluation* manual.

The proposed alignments would not be located within the Alquist-Priolo Special Studies Zone or the Hillside Area. Geotechnical studies have already been appropriately conducted in compliance with the City's *Geotechnical Hazards Evaluation* manual.

City of San Jose General Plan Hazards Chapter

The hazards chapter of the San Jose General Plan provides policies to minimize risk through design and mitigation. As noted below, geotechnical studies are required for development proposals. Geotechnical studies for the project area assess seismic and geologic hazards associated with the BEP and SVRTP alternatives are discussed at the beginning of this section. They will continue to be prepared during final engineering to ensure adequate design and mitigation.

Soils and Geologic Conditions Goal:

Protect the community from the hazards of soil erosion, soil contamination, weak and expansive soils and geologic instability.

Soils and Geologic Conditions Policy 6:

Development in areas subject to soils and geologic hazards should incorporate adequate mitigation measures.

Soils and Geologic Conditions Policy 8:

Development proposed within areas of potential geologic hazards should not be endangered by, nor contribute to, the hazardous conditions on the site or on adjoining properties.

Earthquakes Goal:

Minimize the risk from exposure to seismic activity.

Earthquakes Policy 1:

The City should require that all new buildings be designed and constructed to resist stresses produced by earthquakes.

Earthquakes Policy 4:

The location of public utilities and facilities, in areas where seismic activity could produce liquefaction should only be allowed if adequate mitigation measures can be incorporated into the project.

Earthquakes Policy 5:

The City should continue to require geotechnical studies for development proposals; such studies should determine the actual extent of seismic hazards, optimum location for structures, the advisability of special structural requirements, and the feasibility and desirability of a proposed facility in a specified location.

Earthquakes Policy 6:

Vital public utilities as well as communication and transportation facilities should be located and constructed in a way which maximizes their potential to remain functional during and after an earthquake.

City of Santa Clara General Plan Environmental Quality Element

Program 5.13.2(iii) Regulate the type, location, and intensity of development to mitigate potential adverse effects of unstable soils or seismic hazards.

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