## 3.13 Geology and Soils

Active seismicity represents a key constraint on design and construction for the HST Alignment Alternatives[1]. Portions of HST Alignment Alternatives would require special design, including additional structural ductility and redundancy to withstand severe ground shaking, potential liquefaction, and other types of seismically induced ground failure. Conceptual HST Alignment Alternatives have been designed to cross major faults at grade wherever possible. However, design constraints along several of the alignment alternatives have resulted in crossing faults on aerial structures, and, in one case, in tunnel. In any case, active fault crossings would require special designs to minimize potential damage to the rail lines and other infrastructure as a result of surface fault rupture and surface disruption associated with fault creep.

Construction of mountain crossings for the HST Alignment Alternatives would be constrained by existing unstable slopes and areas of difficult excavation. The tunnels proposed in the alternative alignments would pose additional design and construction issues because of difficult excavation conditions.

Potential geologic impacts that are categorized as high or significant should not be regarded as precluding construction of an alignment alternative or segment, or as necessarily indicating that these would be potentially adverse impacts. Rather, they identify aspects of project design where additional study would be needed and where engineering and design effort would be required to avoid or mitigate the impacts.

### 3.13.1 Regulatory Requirements and Methods of Evaluation

A. REGULATORY REQUIREMENTS

A number of state regulations apply to geologic hazards and engineering geologic practice. The following paragraphs summarize key regulatory provisions; more detailed discussion is deferred to project-level environmental documentation because these regulations, if applicable, relate to site-specific conditions and thus would be applied as appropriate at the project level rather than the program level.

Principal state guidance relating to geologic hazards is contained in the Alquist-Priolo Act (P.R.C. § 2621 *et seq*.) and the Seismic Hazards Mapping Act of 1990 (P.R.C. § 2690–2699.6). The Alquist-Priolo Act prohibits the location of most types of structures for human occupancy across the active traces of faults in earthquake fault zones shown on maps prepared by the state geologist and regulates construction in the corridors along active faults (earthquake fault zones). The Seismic Hazards Mapping Act of 1990 focuses on hazards related to strong ground shaking, liquefaction, and seismically induced landslides. Under its provisions, the state is charged with identifying and mapping areas at risk of strong ground shaking, liquefaction, landslides, and other corollary hazards. The maps are to be used by cities and counties in preparing their general plans and adopting land use policies to reduce and mitigate potential hazards to public health and safety.

Site-specific geotechnical investigations may be prepared to provide a geologic basis for the development of appropriate construction design for proposed projects, including mitigation/ remediation of geologic hazards where this is possible. Geotechnical investigations typically assess the bedrock and Quaternary geology, including soils; the previous history of excavation and fill placement on and in the vicinity of the site for a proposed project; and geologic structure, where relevant. They may also address the requirements of the Alquist-Priolo Act and the Seismic Hazards Mapping Act.

[1] See Section 3.0, Introduction, for an explanation of how this section fits together with the HST Network Alternatives presented in Chapter 7, as well as for an overview of the information presented in the other chapters.

Pursuant to the Surface Mining and Reclamation Act (P.R.C. § 2710 *et seq.*), the State Mining and Geology Board identifies in adopted regulations areas of regional significance that are known to contain mineral deposits judged to be important in meeting the future needs of the area. (See P.R.C. § 2726 and 2790; Title 14 C.C.R. 3550, *et seq.*) The State Mining and Geology Board also adopts state policy for the reclamation of mined lands and certifies local ordinances for the approval of reclamation plans as being consistent with state policies (P.R.C. § 2755–2764, 2774 *et seq.*).

## B. METHOD OF EVALUATION OF IMPACTS

To evaluate potential impacts related to geology and soils, each alignment alternative and each segment have been ranked for potential seismic hazards (ground shaking and ground failure potential), surface rupture hazard (number of active and potentially active fault crossings), slope instability, areas of difficult excavation, presence of oil/gas/geothermal fields (presence of the resource and/or production facilities), and presence of economic mineral resources. The analysis was performed generally on the basis of data available in geographic information systems GIS format, as opposed to detailed site investigations. The geologic data provided in this section are intended for planning purposes and are not intended to be definitive for specific sites. Alignments are evaluated as having high, medium, or low potential for geologic impacts based on the number of geologic constraints identified. Stations and other facilities are evaluated as having high or low potential for geologic impacts, based on the presence or absence of geologic constraints identified. These rankings made it possible to provide a rough comparison of the potential geologic constraints affecting the alternative alignments and station locations.

The following paragraphs describe the ranking process. Table 3.13-1 summarizes the ranking criteria for potential geologic and soils impacts.

**Table 3.13-1**
**Ranking System for Comparing Impacts Related to Geology/Soils/Seismicity**

| Impact Ranking | Seismic Hazards (% of Length) | Active and Potentially Active Fault Crossings (Number of Crossings) | Slope Instability (% of Length) | Difficult Excavation (% of Length) | Oil and Gas Fields (% of Length) | Mineral Resource Sites (Present or Not Present) |
|---|---|---|---|---|---|---|
| **Alignments** | | | | | | |
| High | >50 | 2+ | >10 | >25 | >20 | >20 |
| Medium | 10–50 | 1 | 5–10 | 10–25 | 10–20 | 10–20 |
| Low | <10 | 0 | <5 | <10 | <10 | <10 |
| **Stations/Facilities** | | | | | | |
| High | Present | Present | Present | Present | Present | Present |
| Low | Not present | Not present | Not present | Not present | Not present | Not present |

### Seismic Hazards

Seismic hazards that potentially could constrain the design of proposed facilities were evaluated on the basis of potential for strong ground motion and potential for liquefaction. Areas potentially subject to strong ground motion are defined for this program-level study as areas where there is a 10% probability in 50 years that the peak horizontal ground accelerations in an earthquake will exceed 0.50 g (i.e., areas where peak horizontal ground acceleration may exceed 50% of the acceleration because of gravity) as mapped by the California Geological Survey (formerly the California Division of Mines and Geology) (State of California 1999). This acceleration is used to calculate the horizontal force a structure may be subjected to during an earthquake. For this analysis, liquefaction is conservatively assumed to be possible in all areas where peak ground accelerations could exceed 0.30g, except for areas mapped as underlain by bedrock. Where groundwater levels are not known from existing literature, they are conservatively assumed to be high, contributing to increased potential for liquefaction.

The ranking system for impacts related to seismic hazards used the percentage of each potential alignment within strong ground motion zones and/or potentially liquefiable zones. Station sites are compared by determining whether any portion of the proposed station site would be within a strong ground motion zone or potentially liquefiable zone.

- Alignments: High, medium, or low, based on percentage of alignment length in strong ground motion zones plus the percentage of length in potentially liquefiable zones.
- Stations: High if any part of the site would be within a strong ground motion zone or potentially liquefiable zone; otherwise, low.

Potential for Surface Rupture (Active and Potentially Active Fault Crossings)

Surface rupture hazard is evaluated based on whether any portion of a project alignment or facility would be located within 200 ft (62 m) of the mapped trace of any fault with known or inferred movement during Quaternary time (the past 1.6 million years), i.e., both active and potentially active faults. The State of California defines active faults as those that show evidence for movement in the last 11,000 years. Because of the extreme disruption of transit facilities that can result from surface fault rupture, this analysis deliberately adopted a conservative criterion for the assessment of surface rupture hazard and included potentially active faults, those with known or inferred movement over Quaternary time.

The ranking system for impacts related to surface rupture hazard is based on the number of active and potentially active fault crossings identified.

- Alignments: High, medium, or low, based on number of active and potentially active (Quaternary) fault crossings. Because the probability of fault rupture on potentially active faults is substantially lower than the probability of rupture of active faults, the impact is ranked as high or significant only when active faults are present. Crossing an active fault in tunnel is also ranked as High. If an alignment crosses two or more potentially active faults, but no active faults, the impact is ranked as medium.
- Stations: High if any part of the site is within 200 ft (60 m) of an active or potentially active (Quaternary) fault; otherwise, low.

Slope Instability

Slope stability is evaluated based on the slope gradient and geologic formations or units present along each alignment and at each facility site, as shown in statewide mapping compiled by Jennings (1977, 1991). Each mapped geologic units is assigned a rating for inferred slope stability, based primarily on lithology (physical characteristics of the rock formation) and age. This approach allows the identification of areas at risk for slope instability. A conservative 200-ft (60-m) buffer is included around each identified area of instability.

The ranking system for impacts related to slope instability is based on the percentage of each alignment in potentially unstable zones. Station sites are compared by determining whether any portion of the site is in an area of potential slope instability.

- Alignments: High, medium, or low, based on percentage of alignment length in a potentially unstable zone.
- Stations: High if any part of the site is in a potentially unstable zone; otherwise, low.

Difficult Excavation

Areas of potentially difficult excavation are identified based on bedrock geologic characteristics in combination with the presence of faults of any age, based on statewide mapping compiled by Jennings (1977, 1991) and information from selected 1:250,000-scale geologic map sheets for the study regions published by the California Geological Survey. Each fault crossing is conservatively assumed to be approximately 600 ft (185 m) wide.

The ranking system for impacts related to difficulty of excavation is based on the percentage of each alignment where excavation would be required in identified areas of difficult excavation. Station sites are compared by determining whether any portion of the site is in an identified area of difficult excavation.

- Alignments: High, medium, or low, based on percentage of surface segments in hard rock plus percentage of tunnel segments in fault zones.
- Stations: High if any part of the site is in a hard rock zone or fault zone; otherwise, low.

Oil, Gas, and Geothermal Fields

Areas where the presence of oil, gas, or geothermal resources could constrain project construction or operation are identified on the basis of published resource maps produced by the California Department of Conservation's Division of Oil, Gas, and Geothermal Resources (California Department of Conservation 2001a, 2001b).

The ranking system for impacts related to oil, gas, and geothermal fields is based on the percentage of each proposed alignment in identified oil and gas or geothermal field areas. Station sites are compared by determining whether any portion of the proposed site is in a mapped oil, gas, or geothermal field area.

- Alignment: High, medium, or low, based on percentage of alignment length in mapped oil, gas, or geothermal fields.
- Stations: High if any part of the site is in a mapped oil, gas, or geothermal field; otherwise, low.

Mineral Resources

Areas where the project could affect mineral resource extraction (primarily sand and gravel deposits) are identified on the basis of reports and published maps by the U.S. Geological Survey, and California Geological Survey.

The ranking system for mineral resources impacts is based on the number of mineral resources sites intersected by each alignment. Station sites are compared by determining whether any portion of the site is in a mineral resource area. The potential value of mineral resources varies with time with demand for the resource. Thus, evaluation of specific sites for relative importance will not be considered for this program-level study.

- Alignments: High, medium, or low, based on number of mapped resources within 200 ft (60 m) of a mineral resource area.
- Stations: High if any part of the site is within 200 ft (60 m) of a mineral resource area; otherwise, low.

C. CRITERIA FOR DETERMINING CEQA SIGNIFICANCE

A wide range of potential impacts is considered in the analysis of geology and soils, including seismic hazards, surface rupture hazards, slope instability, safety risks from difficulty in excavation, hazards related to oil and gas fields, and loss of accessibility to mineral resources. Each of these potential geologic and soils impacts is discussed in the following sections. Potential impacts associated with corrosive and expansive soils are difficult to quantify on a regional basis and consequently have not been ranked. However, the following sections briefly discuss the impacts and mitigation of corrosive and expansive soils.

Geologic conditions are evaluated with respect to the impacts the project may have on the local geology, as well as the impact that specific geologic hazards may have on the HST Alignment Alternatives. Impacts of the project related to the geologic environment are characterized on the basis of CEQA statutes and guidelines. Under CEQA guidelines (Appendix G), a project is considered significant if it:

- Exposes people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:
  - Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault. Refer to Division of Mines and Geology Special Publication 42.
  - Strong seismic ground shaking.
  - Seismic-related ground failure, including liquefaction and lateral spreading.
  - iv) Landslides.
- Results in substantial soil erosion or the loss of topsoil.
- Is located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, subsidence, or collapse.
- Is located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property.
- Results in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state.
- Results in the loss of availability of a locally important mineral resource recovery site delineated on a local general plan, specific plan, or other land use plan.

## 3.13.2 Affected Environment

A. STUDY AREA DEFINED

The study area for geology and soils is defined as the corridor extending 200 ft (60 m) on each side of the alignment centerlines, and a 200-ft (60-m) radius around each station site. This distance incorporates all cross sections except deep cuts and fills. As described in Method of Evaluation of Impacts above, alternatives were compared based on the number of sites with potential geologic or soils impacts per alternative, which depends on the length and location of the alignment; broadening the study area to include the entire width of deep cut-and-fill sections would not change the results of the comparison.

B. GENERAL DISCUSSION OF GEOLOGY AND SOILS

The following sections describe key project constraints related to geology and soils.

Seismic Hazards

Seismic hazards are generally classified in two categories: *primary seismic hazards* (surface fault rupture and ground shaking) and *secondary seismic hazards* (liquefaction and other types of seismically induced ground failure, including seismically induced landslides).

Primary: *Surface fault rupture*, or ground rupture, occurs when an active fault ruptures at depth to produce an earthquake, and the rupture propagates to the ground surface. Surface rupture can also occur as a result of slow, gradual motion referred to as *fault creep*. An area's potential for ground rupture is assessed based on the displacement history of the area's faults. Two categories of faults have been defined by the State of California in Special Publication 42 (Hart and Bryant 1997). *Active faults* are those that are known or inferred to have experienced movement in the past 11,000 years and are considered to have a high potential for future ground rupture. *Potentially active*[2] faults are those that are not known to have experienced movement in the past 11,000 years but have moved during Quaternary time (the past 1.6 million years). These faults may also pose a surface rupture hazard, but the hazard is more difficult to evaluate. For the purpose of this study, both active and potentially active faults were evaluated.

*Ground shaking* occurs in response to the release of energy during an earthquake. The energy released travels through subsurface rock, sediment, and soil materials as seismic waves, which result in motion experienced at the ground surface.

Secondary: *Liquefaction* and other types of seismically induced ground failure reflect loss of strength and/or cohesion when earth materials are subjected to strong seismic ground shaking. Earthquakes also can trigger landslides where slopes are prone to failure because of geologic conditions or because of modifications during construction.

Surface fault rupture, ground shaking, and seismically induced ground failure all can result in substantial damage to structures. Thorough assessment of the existing hazard combined with appropriate design and construction can reduce the potential for damage substantially.

Unstable Slopes

Slopes are considered unstable (prone to failure or landslides) when soil or rock strength is insufficient to resist gravitational forces or other loads. Slope instability can occur naturally as a result of a combination of factors such as bedrock bedding and/or fracture patterns, soil or rock strength, and groundwater levels, coupled with steep slopes. Slope failure also can be triggered by seismic activity or by improperly designed construction.

If slope instability is not adequately characterized and mitigated during design and construction, it can cause severe damage to surface and near-surface improvements as well as risks to public safety. However, slope instability generally can be addressed with planning and design.

Areas of Difficult Excavation

Subsurface geologic conditions will largely determine the ease or difficulty of excavation, which will in turn indicate the appropriate excavation technique for use in various areas. For instance, hard unfractured bedrock may be difficult to excavate using bulldozers and other earthmoving equipment, or too resistant to tunneling using a tunnel boring machine; in these areas, blasting may be required. On the other hand, fractured rock that contains groundwater also can be difficult to excavate using tunneling methods. Faulted material can pose an additional challenge by contributing to instability at the tunnel face.

[2] The term *potentially active* is under review for alternative nomenclature by California Geological Survey.

Geologic Resources

Geologic resources in California include oil and gas fields, geothermal fields, and a wide range of mineral resources. The principal constraint associated with oil, gas, geothermal, and mineral resources is the need for planning to ensure that construction of new facilities would not conflict with the removal of economically important resources and would avoid known problem areas to the extent feasible. In addition, the presence of even small (noneconomic) quantities of oil or gas in the subsurface can pose toxic or explosive hazards during construction, requiring specific precautions, and may also necessitate special designs and monitoring during the operation of subsurface structures such as tunnels. Similarly, certain mineral resources, such as serpentine (the source of natural asbestos) can result in hazardous working conditions if not properly managed.

Expansive and Corrosive Soil

Expansive soils shrink and swell as they lose and gain moisture during the local weather cycle. The resulting volumetric changes can heave and crack lightly loaded foundations and slabs. When expansive soils are identified during geotechnical design reports, their impact can be mitigated using standard geotechnical design practices, i.e., removal and replacement with engineered fill, the use of soil improvement techniques such as lime treatment, or by obtaining foundation support below the zone of seasonal moisture variation. Corrosive soils may adversely affect the long-term structural stability of steel and concrete. The impact of corrosive soils can be mitigated by using corrosion-resistant materials during construction.

C. GEOLOGY AND SOILS IN THE BAY AREA TO CENTRAL VALLEY REGION

The following paragraphs provide an overview of key geologic and geomorphologic features in the Bay Area to Central Valley Region, based on Norris and Webb's (1990) overview of California's geomorphic provinces and information from geologic and topographic maps published by the U.S. Geological Survey. The geology along the HST alignments is depicted on Figure 13.3-1.

The Bay Area to Central Valley Region comprises central California from the San Francisco Bay Area (San Francisco and Oakland) south to the Santa Clara Valley and east across the East Bay Hills, Livermore Valley, and Diablo Range to the Central Valley. The Bay Area to Central Valley Region spans two of California's geomorphic provinces: the Coast Ranges province and the Great Valley province.

The Coast Ranges province consists of generally northwest-trending ridges and valleys that form a rugged barrier between the Pacific Coast and inland California. The valley occupied by San Francisco Bay is bordered by the Diablo Range and East Bay Hills on the east and the Santa Cruz Mountains on the west. The Livermore Valley is located between the East Bay Hills and the Diablo Range. Other important valleys within the Coast Ranges province are the Salinas, Napa, and Sonoma Valleys.

The geology of the Diablo Range generally consists of a dense core of partially to completely metamorphosed rocks of the Franciscan Assemblage blanketed by sedimentary rocks of the Great Valley sequence with younger Tertiary Formations along the flanks of the range. The East Bay Hills typically comprise sedimentary rocks of the Great Valley Sequence and younger Tertiary Formations, with rocks of the Franciscan Assemblage along the western flank. In the intervening valleys, the bedrock is blanketed by Quaternary age alluvial deposits.

The Franciscan Assemblage typically consists of a mélange of coherent blocks (ranging in size from a few inches to several miles) of sandstone, siltstone, chert, and greenstone in a matrix of sheared shale and serpentinite. Slopes in the sheared shale and serpentinite often are unstable. The Great Valley Sequence consists of a series of non-metamorphosed sedimentary rocks ranging in age from Cretaceous to early Tertiary. They typically comprise marine sandstone and shale with occasional beds of conglomerate. The Tertiary Formations generally comprise poorly to moderately cemented claystone, shale, sandstone, and conglomerate. Slopes in the Tertiary units can be unstable, even at low angles, when the degree of compaction and cementation is low.

Along the margins of San Francisco Bay, the Quaternary sediments consist of intertidal deposits or organic rich bay mud, older alluvium, and alluvial fan deposits, locally blanketed by artificial fill. In the Livermore and Santa Clara Valleys, the Quaternary sediments typically comprise sand, gravel and clay. Locally the gravel in the Livermore Valley is mined as aggregate.

The Great Valley province comprises a large, elongated, north-trending valley situated between the Coast Ranges on the west and the Sierra Nevada on the east. Much of the Great Valley is at elevations near sea level (Norris and Webb 1990). The valley is a structurally controlled basin, with faults occurring at the boundaries between the valley and adjacent mountain ranges. Quaternary alluvium was deposited in the basin as it subsided. The Quaternary alluvium comprises fluvial, alluvial, and terrace deposits consisting of clay, silt, sand, gravel, and cobbles. The Quaternary sediments are generally finer-grained near the center of the valley and coarser-grained along the flanks of the valley. Individual geologic units include the Modesto, Riverbank, Dos Palos, Los Banos, San Luis Ranch, and Patterson Formations.

## 3.13.3 Environmental Consequences

### A. NO PROJECT ALTERNATIVE

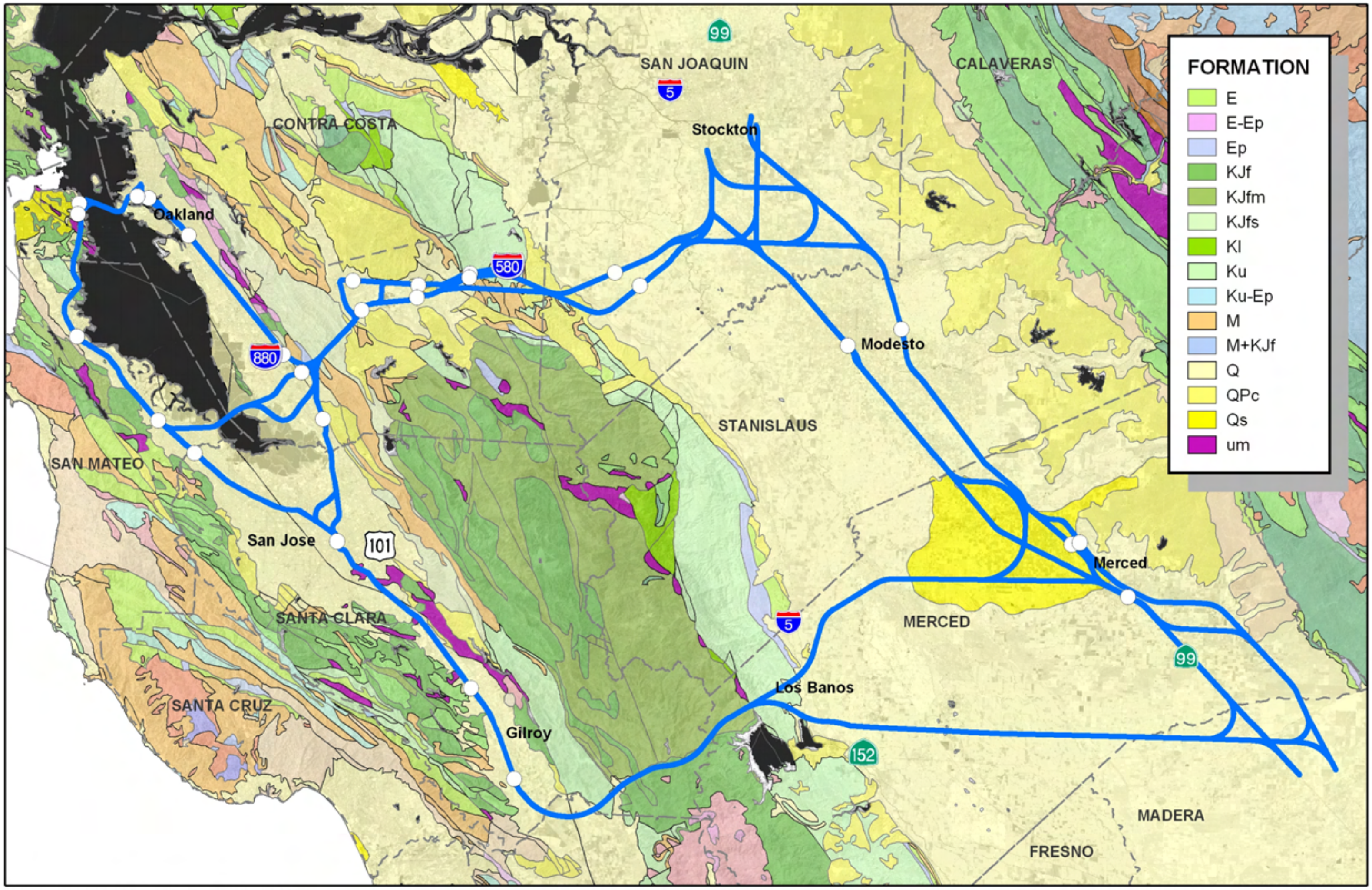
Existing conditions are as of 2006. The No Project Alternative includes existing transportation infrastructure plus all planned, approved, and funded projects that can reasonably be expected to be in operation by 2030. This analysis assumed that existing major infrastructure (bridges, for example) was designed, has been retrofitted, or is scheduled to be retrofitted to meet current design standards for seismic safety and other geologic constraints, and that future projects included in the No Project Alternative would incorporate similar safeguards as part of the development, design, and construction process. However, it is not possible to eliminate or mitigate all geologic hazards through design and construction. Some types of geologic hazards (seismic hazards in particular) are unpredictable. While it is difficult to evaluate the change in hazards (potential for geologic impacts) between existing conditions and No Project conditions, it can be assumed that some improvements in technology and materials as well as more stringent design codes will be implemented in the next 20 years to address seismic design of new structures. Thus the No Project Alternative would be somewhat improved from the existing conditions, but existing geologic risks were assumed to be representative of geologic risks under the No Project Alternative.

### B. HIGH-SPEED TRAIN ALIGNMENT ALTERNATIVES

Overall, the HST Alignment Alternatives would have the following impacts before mitigation: (1) ground shaking and ground failure, (2) ground rupture, (3) slope instability, (4) difficulty in excavation, and (5) hazards related to oil and gas fields.

**Ground Shaking and Failure**. Seismic hazards evaluated include ground shaking and ground failure. The HST Alignment Alternatives and facilities could cause risks to workers and public safety attributable to the collapse or toppling of facilities, either during construction or after completion, as a result of strong earthquakes. The HST Alignment Alternatives and facilities also could create risks to public safety from automobile accidents or the interruption of automobile circulation, if strong earthquakes cause a derailment. HST facilities could sustain damage from secondary hazards such as settlement over soft or filled ground.

**Ground Rupture.** The HST Alignment Alternatives and facilities could cause risks to workers and public safety as a result of ground rupture along active faults, either during construction or after completion. The HST Alignment Alternatives and facilities also could create secondary public safety




Source: Landsat TM 1985; CW Jennings 1977

March 29, 2007

*California High-Speed Train Program EIR/EIS*

**Legend**



High-Speed Train Alignment Alternative and Station Location Options

County Boundaries



**Figure 3.13-1**
**Geology in the Study Region**

risks caused by damage to highways or interruption of these transportation services, in the event of train derailment caused by ground rupture along active faults.

**Slope Instability.** The HST Alignment Alternatives and facilities could cause risks to workers and public safety attributable to the failure of natural or construction cut slopes or retention structures.

**Difficulty in Excavation.** The HST Alignment Alternatives and facilities could cross areas with hard, unfractured bedrock that would be difficult to excavate using methods other than blasting, which may pose a safety risk. Faulted materials that may be present can result in instability in the face of a tunnel area, another potential hazard.

**Hazards Related to Oil and Gas Fields.** The HST could be adversely affected by the potential for migration of potentially explosive and/or toxic gases into subsurface facilities, such as tunnels or underground stations.

This analysis focused on comparing the difference in impacts anticipated with the various HST Alignment Alternatives compared to 2030 No Project conditions.

Table 3.13-2 shows geologic impact ratings for the HST Alignment Alternatives (an impact is a constraint to development) (see Table 3.13-A-1 in Appendix 3.13-A for more detail). They include:

- Seismic hazards and the potential for strong seismic ground shaking and liquefaction.
- Active and potentially active fault crossings.
- Unstable slopes.
- Difficult excavation of tunnels and deep cuts.
- Impacts on oil and gas fields.
- Impacts on mineral resources.

**Table 3.13-2. Geology and Soils Summary Data Table for Alignment Alternatives and Station Location Option Comparisons**

| Corridor | Possible Alignments | Alignment Alternative | Seismic Hazards | Active and Potentially Active Fault Crossings | Slope Instability | Difficult Excavation | Oil and Gas Fields | Mineral Resources |
|---|---|---|---|---|---|---|---|---|
| **San Francisco to San Jose: Caltrain** | 1 of 1 | San Francisco to Dumbarton | H | M | L | L | L | L |
| | 1 of 1 | Dumbarton to San Jose | H | M | L | L | L | L |
| **Station Location Options** | | | | | | | | |
| Transbay Transit Center | | | H | L | L | L | L | L |
| 4th and King (Caltrain) | | | H | L | L | L | L | L |
| Millbrae/SFO | | | H | L | L | L | L | L |
| Redwood City (Caltrain) | | | H | L | L | L | L | L |
| Palo Alto (Caltrain) | | | H | L | L | L | L | L |
| **Oakland to San Jose: Niles/I-880** | 1 of 2 | West Oakland to Niles Junction | H | M | L | L | L | L |
| | | 12th Street/City Center to Niles Junction | H | M | L | L | L | L |
| | 1 of 2 | Niles Junction to San Jose via Trimble | H | H | L | L | L | L |
| | | Niles Junction to San Jose via I-880 | H | H | L | L | L | L |

| Corridor | Possible Alignments | Alignment Alternative | Seismic Hazards | Active and Potentially Active Fault Crossings | Slope Instability | Difficult Excavation | Oil and Gas Fields | Mineral Resources |
|---|---|---|---|---|---|---|---|---|
| **Station Location Options** | | | | | | | | |
| West Oakland/7th Street | | | H | L | L | L | L | L |
| 12th Street/City Center | | | H | L | L | L | L | L |
| Coliseum/Airport | | | H | L | L | L | L | L |
| Union City (BART) | | | H | L | L | L | L | L |
| Fremont (Warm Springs) | | | H | L | L | L | L | L |
| **San Jose to Central Valley: Pacheco Pass** | 1 of 1 | Pacheco | H | H | M | M | L | L |
| | 1 of 3 | Henry Miller (UPRR Connection) | M | M | L | L | L | L |
| | | Henry Miller (BNSF Connection) | M | M | L | L | L | L |
| | | GEA North | M | M | L | L | L | L |
| **Station Location Options** | | | | | | | | |
| San Jose (Diridon) | | | H | L | L | L | L | L |
| Morgan Hill (Caltrain) | | | H | L | L | L | L | L |
| Gilroy (Caltrain) | | | H | L | L | L | L | L |
| **East Bay to Central Valley: Altamont Pass** | 1 of 4 | I-680/ 580/UPRR | H | H | L | M | L | L |
| | | I-580/ UPRR | H | H | L | M | L | L |
| | | Patterson Pass/UPRR | H | H | M | H | L | L |
| | | UPRR | H | H | L | M | L | L |

| Corridor | Possible Alignments | Alignment Alternative | Seismic Hazards | Active and Potentially Active Fault Crossings | Slope Instability | Difficult Excavation | Oil and Gas Fields | Mineral Resources |
|---|---|---|---|---|---|---|---|---|
| | 1 of 4 | Tracy Downtown (BNSF Connection) | M | M | L | L | L | L |
| | | Tracy ACE Station (BNSF Connection) | M | H | L | L | L | L |
| | | Tracy ACE Station (UPRR Connection) | M | H | L | L | L | L |
| | | Tracy Downtown (UPRR Connection) | M | M | L | L | L | L |
| | 2 of 2 | East Bay Connections WPRR to UPRR | H | H | L | L | L | L |
| | | East Bay Connections UP to UPRR | H | M | L | L | L | L |
| **Station Location Options** | | | | | | | | |
| Pleasanton (I-680/Bernal Rd) | | | H | L | L | L | L | L |
| Pleasanton (BART) | | | H | L | L | L | L | L |
| Livermore (Downtown) | | | H | L | L | L | L | L |
| Livermore (I-580) | | | H | L | L | L | L | L |
| Livermore (Greenville Road/UPRR) | | | H | L | L | L | L | L |
| Livermore (Greenville Road/I-580) | | | H | L | L | L | L | L |
| Tracy (Downtown) | | | H | L | L | L | L | L |
| Tracy (ACE) | | | H | L | L | L | L | L |

| Corridor | Possible Alignments | Alignment Alternative | Seismic Hazards | Active and Potentially Active Fault Crossings | Slope Instability | Difficult Excavation | Oil and Gas Fields | Mineral Resources |
|---|---|---|---|---|---|---|---|---|
| **San Francisco Bay Crossings** | 1 of 2 | Trans Bay Crossing—Transbay Transit Center | H | L | L | L | L | L |
| | | Trans Bay Crossing—4th & King | H | L | L | L | L | L |
| | 1 of 6 | Dumbarton (High Bridge) | H | H | L | L | L | L |
| | | Dumbarton (Low Bridge) | H | H | L | L | L | L |
| | | Dumbarton (Tube) | H | H | L | L | L | L |
| | | Fremont Central Park (High Bridge) | H | H | L | L | L | L |
| | | Fremont Central Park (Low Bridge) | H | H | L | L | L | L |
| | | Fremont Central Park (Tube) | H | H | L | L | L | L |
| **Station Location Options** | | | | | | | | |
| Union City (Shinn) | | | H | H | L | L | L | L |
| **Central Valley** | 1 of 6 | BNSF—UPRR | L | L | L | L | L | L |
| | | BNSF | L | L | L | L | L | L |
| | | UPRR N/S | L | L | L | L | L | L |
| | | BNSF Castle | L | L | L | L | L | L |
| | | UPRR—BNSF Castle | L | L | L | L | L | L |

| Corridor | Possible Alignments | Alignment Alternative | Seismic Hazards | Active and Potentially Active Fault Crossings | Slope Instability | Difficult Excavation | Oil and Gas Fields | Mineral Resources |
|---|---|---|---|---|---|---|---|---|
| | | UPRR—BNSF | L | L | L | L | L | L |
| | | | | | | | | |
| **Station Location Options** | | | | | | | | |
| Modesto (Downtown) | | | L | L | L | L | L | L |
| Briggsmore (Amtrak) | | | L | L | L | L | L | L |
| Merced (Downtown) | | | L | L | L | L | L | L |
| Castle AFB | | | L | L | L | L | L | L |

Table 3.13-3 shows the actual fault crossing by alignment alternative.

**Table 3.13-3. Fault Crossings by Alignment and Segment**

| Corridor | Possible Alignments | Alignment | Fault(s) Crossed | Active of Potentially Active? | Crossed above, at, or below Grade? |
|---|---|---|---|---|---|
| **San Francisco to San Jose: Caltrain** | 1 of 1 | San Francisco to Dumbarton | San Bruno Fault | Potentially Active | At Grade |
| | 1 of 1 | Dumbarton to San Jose | Buried Trace of Unnamed Fault | Potentially Active | At Grade |
| Transbay Transit Center | | | None | | |
| 4th and King (Caltrain) | | | None | | |
| Millbrae/SFO | | | None | | |
| Redwood City (Caltrain) | | | None | | |
| Palo Alto (Caltrain) | | | None | | |
| **Oakland to San Jose: Niles/I-880** | 1 of 2 | West Oakland to Niles Junction | Hayward Fault | Active | At Grade |
| | | 12th Street/City Center to Niles Junction | Hayward Fault | Active | At Grade |
| | 1 of 2 | Niles Junction to San Jose via Trimble | Hayward Fault<br>Silver Creek Fault | Active<br>Potentially Active | At Grade<br>Above Grade |
| | | Niles Junction to San Jose via I-880 | Hayward Fault<br>Silver Creek Fault | Active<br>Potentially Active | At Grade<br>Above Grade |
| West Oakland/7th Street | | | None | | |
| 12th Street/City Center | | | None | | |
| Coliseum/Airport | | | None | | |
| Union City (BART) | | | None | | |
| Fremont (Warm Springs) | | | None | | |
| **San Jose to Central Valley: Pacheco Pass** | 1 of 1 | Pacheco | Silver Creek Fault<br>Calaveras Fault | Potentially Active<br>Active | At Grade<br>At Grade |
| | 1 of 3 | Henry Miller (UPRR Connection) | Ortigalita Fault | Active | At Grade |
| | | Henry Miller (BNSF Connection) | Ortigalita Fault | Active | At Grade |
| | | GEA North | Ortigalita Fault | Active | At Grade<br>Embankment |

| Corridor | Possible Alignments | Alignment | Fault(s) Crossed | Active of Potentially Active? | Crossed above, at, or below Grade? |
|---|---|---|---|---|---|
| San Jose (Diridon) | | | None | | |
| Morgan Hill (Caltrain) | | | None | | |
| Gilroy (Caltrain) | | | None | | |
| **East Bay to Central Valley: Altamont Pass** | 1 of 4 | I-680/ 580/UPRR | Calaveras Fault<br>Pleasanton Fault<br>Livermore Fault<br>Greenville Fault | Active<br>Active<br>Potentially Active<br>Active | Tunnel[3]<br>Above Grade<br>Above Grade<br>Above Grade |
| | | I-580/ UPRR | Calaveras Fault<br>Livermore Fault<br>Greenville Fault | Active<br>Potentially Active<br>Active | Tunnel[3]<br>At Grade<br>Above Grade |
| | | Patterson Pass/UPRR | Calaveras Fault<br>Livermore Fault<br>Greenville Fault<br>Corral Hallow Fault | Active<br>Potentially Active<br>Active<br>Potentially Active | Tunnel[3]<br>At Grade<br>Above Grade<br>At Grade |
| | | UPRR | Calaveras Fault<br>Livermore Fault<br>Greenville Fault | Active<br>Potentially Active<br>Active | Tunnel[3]<br>At Grade<br>Above Grade |
| | 1 of 4 | Tracy Downtown (BNSF Connection) | Vernalis Fault | Active | At Grade |
| | | Tracy ACE Station (BNSF Connection) | Vernalis Fault<br>San Joaquin Fault | Active<br>Potentially Active | At Grade<br>At Grade |
| | | Tracy ACE Station (UPRR Connection) | Vernalis Fault<br>San Joaquin Fault | Active<br>Potentially Active | At Grade<br>At Grade |
| | | Tracy Downtown (UPRR Connection) | Vernalis Fault | Active | At Grade |
| | 2 of 2 | East Bay Connections (WPRR to UPRR) | Hayward Fault<br>Mission Fault | Active<br>Potentially Active | At Grade<br>At Grade |
| | | East Bay Connections (UP to UPRR) | Mission Fault | Potentially Active | At Grade |
| Pleasanton (I-680/Bernal Rd) | | | None | | |
| Pleasanton (BART) | | | None | | |
| Livermore (Downtown) | | | None | | |
| Livermore (I-580) | | | None | | |

[3] Following circulation of the Draft Program EIR/EIS, FRA and the Authority discovered that the location of the Calaveras Fault was incorrectly shown on Figure 2.D-60, Appendix 2D. The correct location of the fault line is 1,500 feet to the west. As a result, this table and Figure 2.D-60 have been corrected to show that the HSR alignment would cross this fault in tunnel.

| Corridor | Possible Alignments | Alignment | Fault(s) Crossed | Active of Potentially Active? | Crossed above, at, or below Grade? |
|---|---|---|---|---|---|
| Livermore (Greenville Road/UPRR) | | | None | | |
| Livermore (Greenville Road/I-580) | | | None | | |
| Tracy (Downtown) | | | None | | |
| Tracy (ACE) | | | None | | |
| **San Francisco Bay Crossings** | 1 of 2 | Trans Bay Crossing – Transbay Transit Center | None | | |
| | | Trans Bay Crossing – 4th & King | None | | |
| | 1 of 6 | Dumbarton (High Bridge) | Buried Trace of Unnamed Fault<br>Silver Creek Fault<br>Hayward Fault<br>Mission Fault | Potentially Active<br>Potentially Active<br>Active<br>Potentially Active | At Grade<br>At Grade<br>Above Grade<br>At Grade |
| | | Dumbarton (Low Bridge) | Buried Trace of Unnamed Fault<br>Silver Creek Fault<br>Hayward Fault<br>Mission Fault | Potentially Active<br>Potentially Active<br>Active<br>Potentially Active | At Grade<br>At Grade<br>Above Grade<br>At Grade |
| | | Dumbarton (Tube) | Buried Trace of Unnamed Fault<br>Silver Creek Fault<br>Hayward Fault<br>Mission Fault | Potentially Active<br>Potentially Active<br>Active<br>Potentially Active | At Grade<br>At Grade<br>Above Grade<br>At Grade |
| | | Fremont Central Park (High Bridge) | Buried Trace of Unnamed Fault<br>Silver Creek Fault<br>Hayward Fault<br>Mission Fault | Potentially Active<br>Potentially Active<br>Active<br>Potentially Active | At Grade<br>At Grade<br>Above Grade<br>At Grade |
| | | Fremont Central Park (Low Bridge) | Buried Trace of Unnamed Fault<br>Silver Creek Fault<br>Hayward Fault<br>Mission Fault | Potentially Active<br>Potentially Active<br>Active<br>Potentially Active | At Grade<br>At Grade<br>Above Grade<br>At Grade |
| | | Fremont Central Park (Tube) | Buried Trace of Unnamed Fault<br>Silver Creek Fault<br>Hayward Fault<br>Mission Fault | Potentially Active<br>Potentially Active<br>Active<br>Potentially Active | At Grade<br>At Grade<br>Above Grade<br>At Grade |
| Union City (Shinn) | | | Within AP Fault Hazard Zone for | Active | Above Grade |

| Corridor | Possible Alignments | Alignment | Fault(s) Crossed | Active of Potentially Active? | Crossed above, at, or below Grade? |
|---|---|---|---|---|---|
| | | | Hayward Fault | | |
| **Central Valley** | 1 of 6 | BNSF—UPRR | None | | |
| | | BNSF | None | | |
| | | UPRR N/S | None | | |
| | | BNSF Castle | None | | |
| | | UPRR—BNSF Castle | None | | |
| | | UPRR—BNSF | None | | |
| **Station Location Options** | | | | | |
| Modesto (Downtown) | | | None | | |
| Briggsmore (Amtrak) | | | None | | |
| Merced (Downtown) | | | None | | |
| Castle AFB | | | None | | |

C. ALTERNATIVES BY CORRIDOR

San Francisco to San Jose Corridor

The San Francisco to San Jose alignment alternatives are located in an area of potentially strong ground motion and are potentially subject to liquefaction and/or other types of seismically induced ground failure (Figure 3.13-2, Areas Subject to Strong Ground Motion, and Figure 3.13-3, Areas of Potential Liquefaction). The alignment alternatives cross buried traces of two potentially active faults but do not cross any active faults (Figure 3.13-4a, Quaternary Faults and Alquist-Priolo Zoned Faults). Overall, the alignment alternatives ranked high with respect to seismic hazards and medium with respect to fault rupture.

Generally, the proposed alignment alternatives in the San Francisco to San Jose corridor cross the nearly flat topography of the San Francisco Bay margin and the Santa Clara Valley. Thus, there would be little to no concern about slope stability or difficult excavation along these alternatives. The alignments do not cross oil and gas fields or areas of significant mineral resources.

Oakland to San Jose Corridor

The alignment alternatives in the Oakland to San Jose corridor are located in areas of potentially strong ground motion, and to a lesser extent, areas potentially subject to liquefaction and/or other types of seismically induced ground failure (Figures 3.13-2 and 3.13-3). Multiple crossings of the active Hayward fault would also be a concern. The Union City to Niles Junction alignment segment crosses the Hayward fault north of Niles Junction, while the Niles Junction to Niles Wye segment crosses back over the Hayward fault, south of Niles Junction. In addition, both the Niles Junction to San Jose via Trimble alignment alternative and the Niles Junction to San Jose via I-880 alignment alternative cross a buried trace of the potentially active Silver Creek fault. Overall, the alignment alternatives in this corridor are ranked high with respect to both seismic hazards and fault rupture.

Generally, the proposed alignment alternatives in the Oakland to San Jose corridor cross the nearly flat topography of the Santa Clara Valley and the alluvial fans between the East Bay hills and San

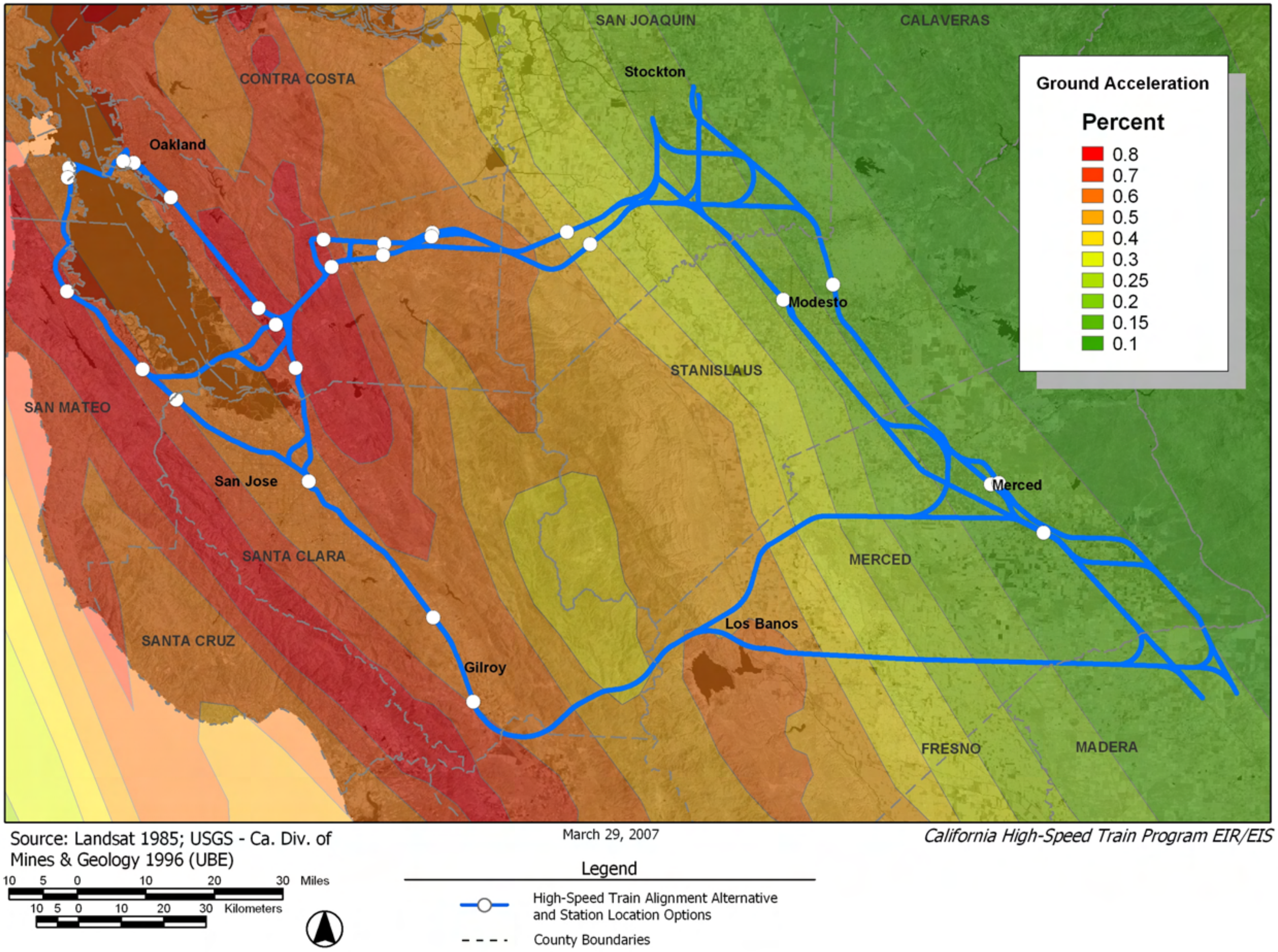





**Figure 3.13-2**
**Areas Subject to Strong Ground Motion in the Study Region**

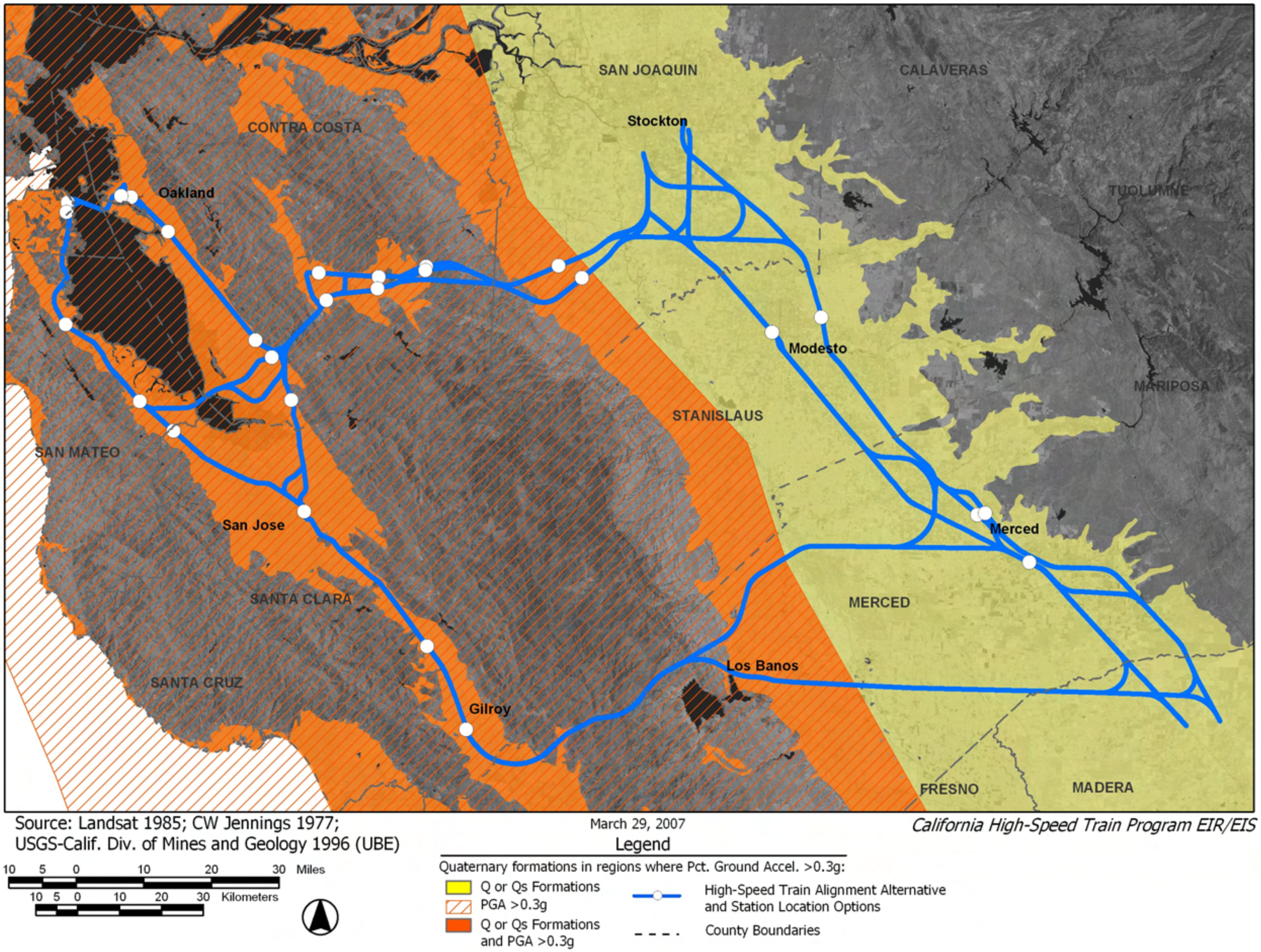



**Figure 3.13-3**
**Areas of Potential Liquefaction in the Study Region**

Francisco Bay margin. Thus, there would be little to no concern about slope stability or difficult excavation along these alignment alternatives. The alignment segments Union City to Niles Junction, Niles Junction to Niles Wye, and Niles Wye to Warm Springs traverse the Niles Cone, an area identified by the state as a potential sand and gravel resource. However, as part of an existing railroad right-of-way or immediately adjacent to the existing right-of-way, they are not expected to affect any current quarry operations. These alignment alternatives do not cross oil and gas fields (See Figure 13.3-5, Oil and Gas Fields).

San Jose to Central Valley Corridor

The Pacheco alignment is located in areas of potentially strong ground motion, and to a lesser extent, areas potentially subject to liquefaction and/or other types of seismically induced ground failure (Figures 3.13-2 and 3.13-3). The Henry Miller and GEA North alignment alternatives are generally located in areas of low to moderate ground motion and liquefaction potential. The Pacheco alignment alternative crosses the potentially active Silver Creek fault and the active Calaveras fault, while both the GEA North and Henry Miller alignment alternatives cross the active Ortigalita fault near San Luis Reservoir. Overall, the alignment alternatives in this corridor ranked medium to high with respect to both seismic hazards and fault rupture.

The proposed Gilroy to San Luis Reservoir alignment segment crosses the Diablo Range at grade and in a series of tunnels. Locally, steep slopes along this segment are potentially unstable. (See Figure 13.3-6, Areas of Unstable Slopes). There would be little to no concern about slope stability where the Pacheco alignment crosses the nearly flat topography of the Santa Clara Valley and the Central Valley or in the tunnels through the Diablo Range. Considering the length of the alignment, the potential for slope stability impacts is low along the Pacheco alignment.

The most likely areas of difficult excavation would be the proposed cut slopes and tunnels in the Diablo Range between Gilroy and the San Luis Reservoir. Rocks of the Franciscan Complex are highly variable and include some rock units that are typically hard, and fracture zones are common along this alignment segment. The Pacheco alignment alternatives between the Diridon and Morgan Hill stations also traverses an area identified by the state as a potential sand and gravel resource. These alignment alternatives do not cross oil and gas fields or areas of significant mineral resources.

East Bay to Central Valley Corridor

In the East Bay to Central Valley corridor the alignment alternatives are located in areas of potentially strong ground motion, and to a lesser extent, areas potentially subject to liquefaction and/or other types of seismically induced ground failure (Figures 3.13-2 and 3.13-3). The active Hayward, Calaveras, Greenville, Pleasanton, and Vernalis faults and the potentially active Mission, Livermore, Corral Hallow, and San Joaquin fault crossings would also be a concern along these alignment alternatives (Figures 3.13-4a, b, and c). During the development of the conceptual alignments, extensive efforts were made to cross all active faults at grade, or, if absolutely necessary, on an aerial structure. Special efforts were made to not to cross an active fault in a tunnel configuration, which is deemed a major design issue—a severe hazard.

Following circulation of the Draft Program EIR/EIS, FRA and the Authority discovered that the location of the Calaveras Fault was incorrectly shown on Figure 2.D-60, Appendix 2D of the Draft Program EIR/EIS. The correct location of the fault line is approximately 1,500 feet to the west. Figure 3.13-7 shows the prior incorrect location and the correct location of the Calaveras fault line. As shown on this figure and on the revised Figure 2.D-60, Appendix 2D, as proposed this HST alignment alternative would cross the corrected fault line in tunnel.

To cross this fault line in tunnel would require additional design and mitigation work to address safety issues. Alternatively, to meet the Authority's objective of crossing major fault zones at grade, as noted in Chapter 2, would require redesign and realignment of the Altamont Alignment alternatives and would result in increased environmental impacts, as well as increased travel times for the Altamont alignment alternatives. Overall, the alignment alternatives are ranked high in this corridor with respect to both seismic hazards and fault rupture.

All of the proposed alignment segments that cross the Diablo Range traverse steep and potentially unstable slopes. There would be little to no concern about slope stability where the alignments cross the nearly flat topography of the San Francisco Bay margin, the Livermore Valley, and the Central Valley or where they cross the East Bay hills in tunnel. In addition, considering the lengths of the alignments, the potential for slope stability impacts is low through the Diablo Range.

The most likely areas of difficult excavation would be the tunnel through the East Bay Hills and the Diablo Range crossings where rocks of the Franciscan Complex are highly variable and include some rock units that are typically hard, and fracture zones are common. In the Livermore Valley, the alignment alternatives between Livermore and Pleasanton traverse an area identified by the state as a potential sand and gravel resource. However, as part of an existing railroad or highway right-of-way or immediately adjacent to the railroad right-of-way, they are not expected to affect any current quarry operations. These alignment alternatives do not cross oil and gas fields.

San Francisco Bay Crossings

The San Francisco Bay Crossings are located in areas of potentially strong ground motion and are potentially subject to liquefaction and/or other types of seismically induced ground failure (Figures 3.13-2 and 3.13-3). The Transbay alignment alternative does not cross any known active or potentially active faults. However, the Dumbarton and Fremont Central Park alignment alternatives cross the potentially active Silver Creek fault, the active Hayward fault and the potentially active Mission fault. Overall, the alignment alternatives in the Bay Crossings are ranked high with respect to seismic hazards, and the potential for fault rupture is ranked low for the Transbay alignment alternative and high for the Dumbarton alignment alternative.

These alternative alignments do not traverse any steep and potentially unstable slopes or areas of difficult bedrock excavation and do not cross oil and gas fields. The eastern end of Dumbarton and Fremont Central Park alignment alternatives traverses the Niles Cone, an area identified by the state as a potential sand and gravel resource. However, this eastern section of both the Dumbarton and Fremont Central Park alignment alternatives pass through urban areas and/or are located along existing railroad right of ways and they are not expected to affect any current quarry operations.

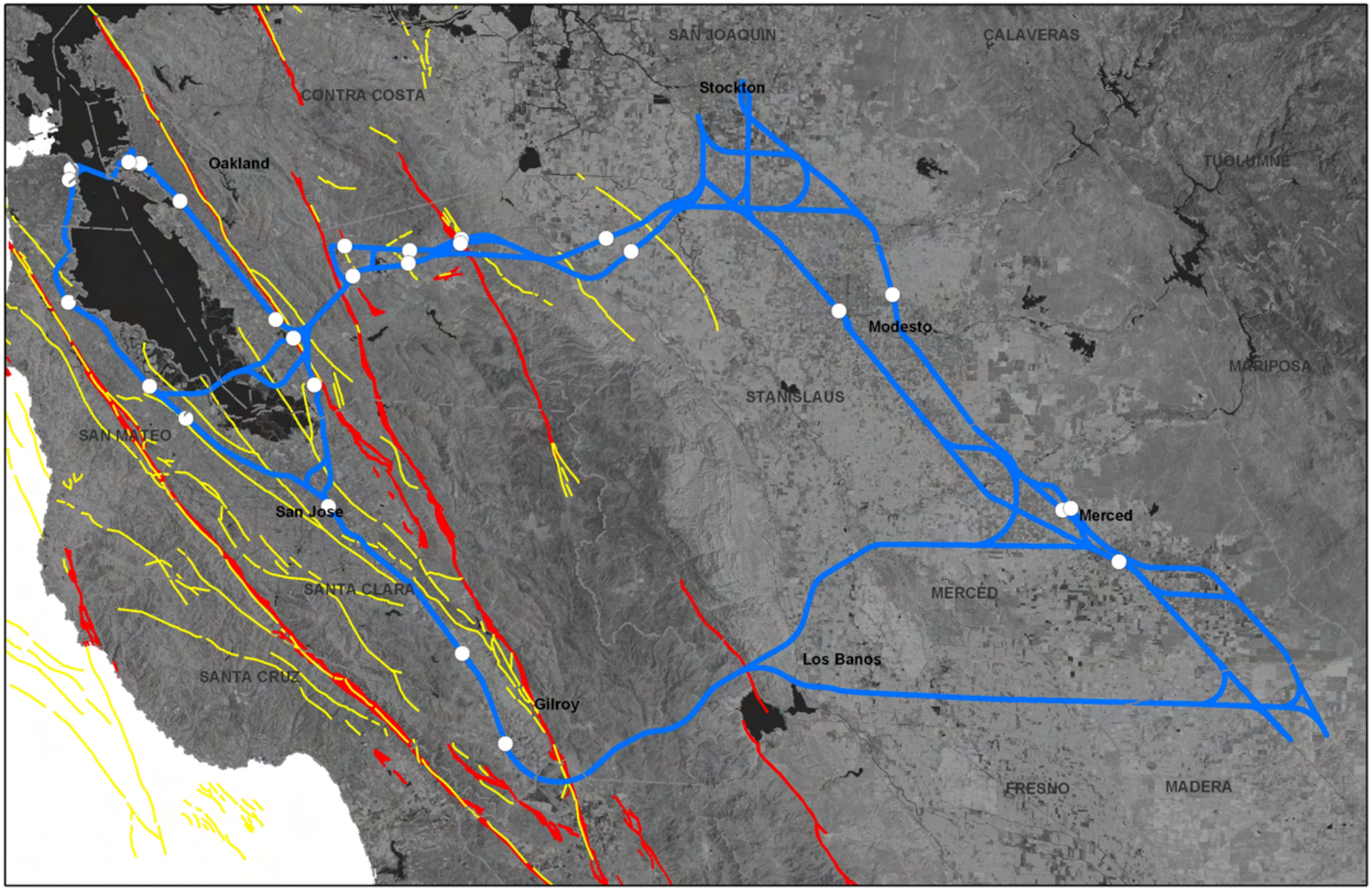
Central Valley Corridor

In the Central Valley corridor, the alignment alternatives are located in areas of potentially low to moderate ground motion and low potential for liquefaction and other types of seismically induced ground failure (Figures 3.13-2 and 3.13-3). Active fault crossings are not a concern along these alignments. Overall, the alignment alternatives in this corridor are ranked low in this region with respect to both seismic hazards and fault rupture.

There would be little to no concern about slope stability or difficult excavation in the Central Valley, and these alignment alternatives generally do not cross oil and gas fields or areas of significant mineral resources.

## 3.13.4 Role of Design Practices in Avoiding and Minimizing Effects

The Authority has avoided and minimized to the extent possible potential effects related to major geologic hazards such as major fault crossings, oil fields, and landslide areas throughout extensive alignment studies completed prior to and as part of the prior HST system program EIR/EIS process. The Authority's objective is to avoid fault crossings in tunnel and to avoid fault crossings on aerial sections,




Source: Landsat 1985; CW Jennings 1994; Alquist-Priolo 2002

March 29, 2007

*California High Speed Train Program EIR/EIS*

10 5 0 10 20 30 Miles

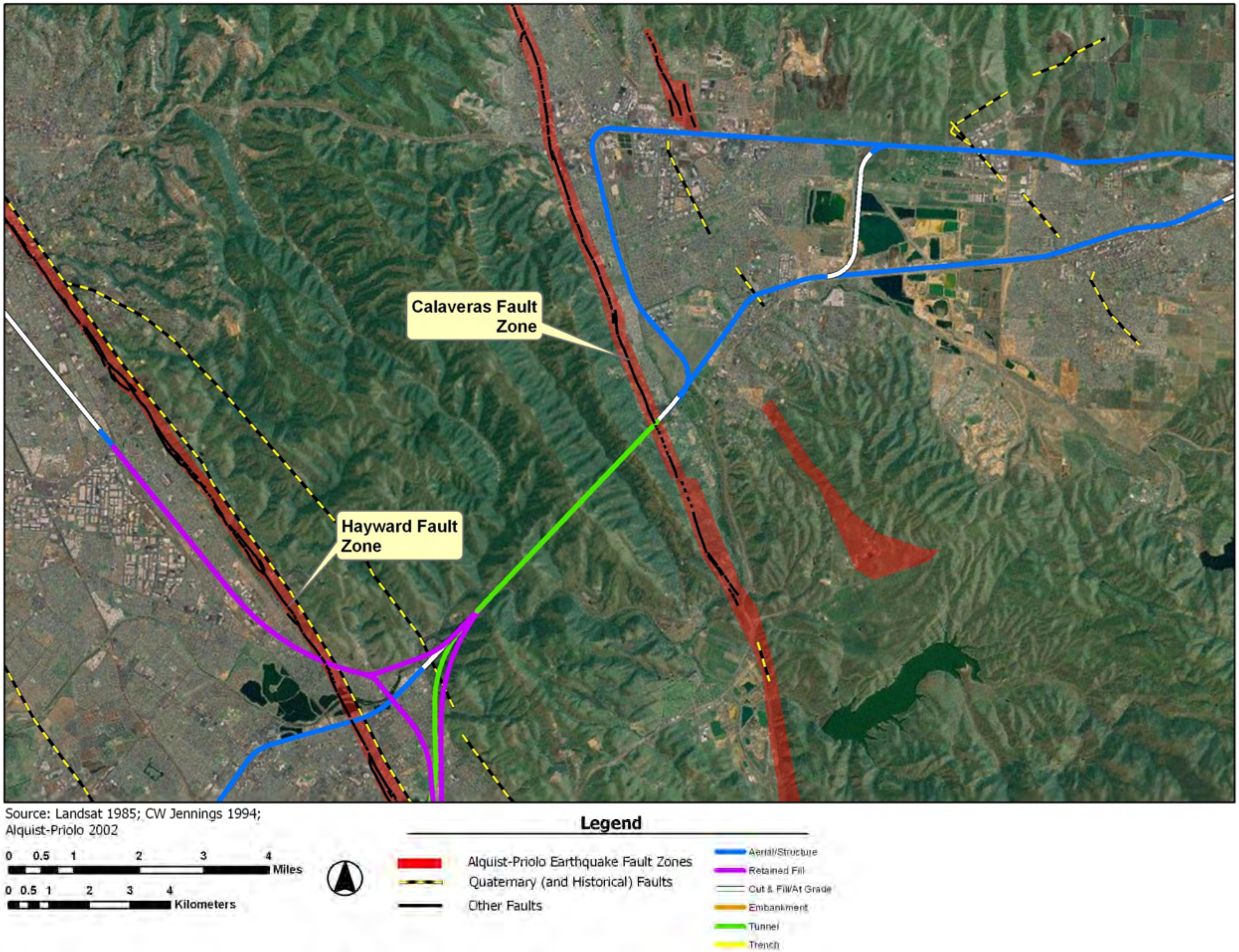
10 5 0 10 20 30 Kilometers

Legend

- Quaternary (and Historical) Faults
- Alquist-Priolo Earthquake Fault Zones
- High-Speed Train Alignment Alternative and Station Location Options
- County Boundaries

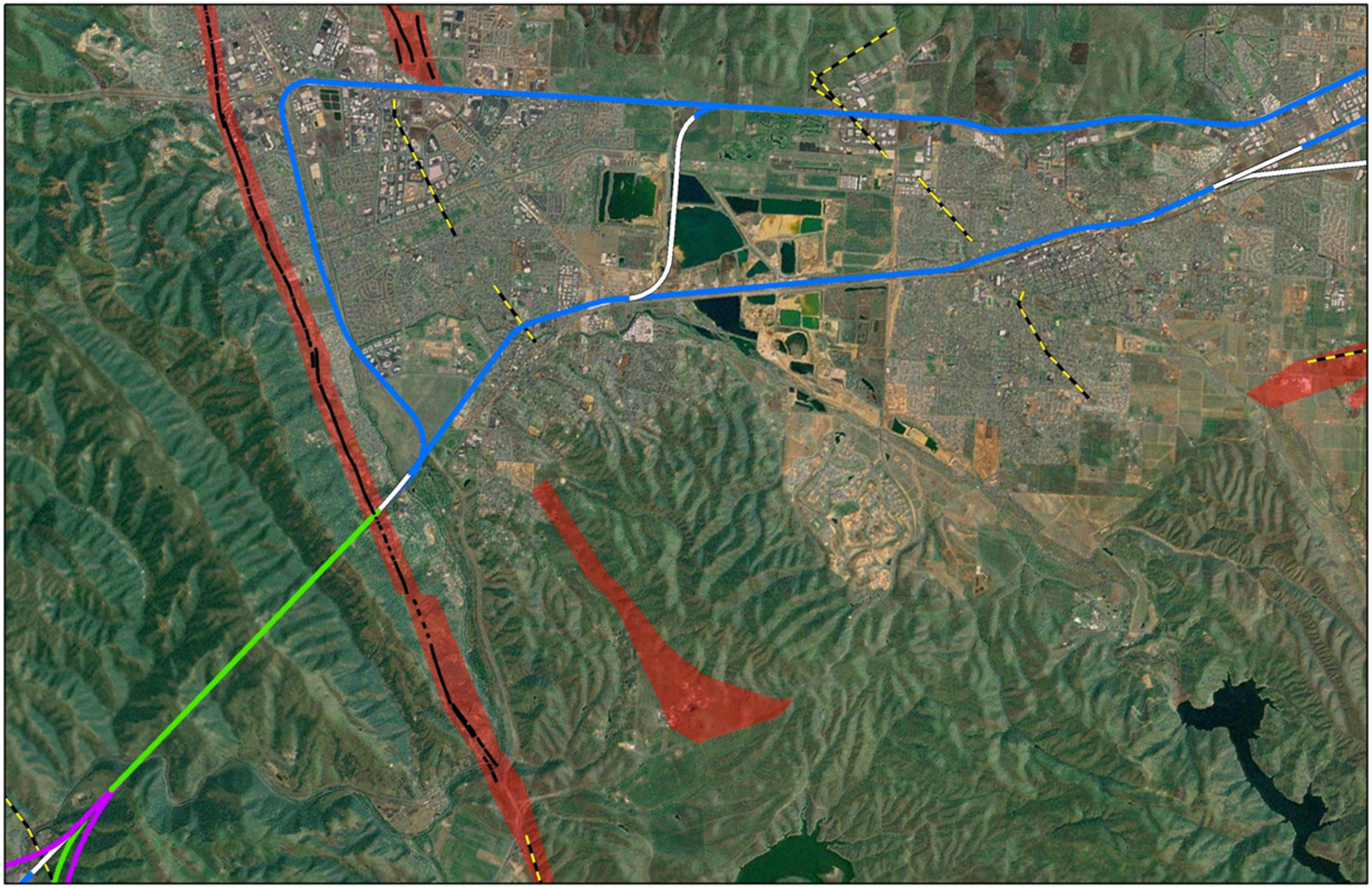
U.S. Department of Transportation
**Federal Railroad Administration**

**Figure 3.13-4a**
**Quaternary Faults and Alquist-Priolo Zoned Faults in the Study Region**




U.S. Department of Transportation
**Federal Railroad Administration**

**Figure 3.13-4b**
**Quaternary Faults and Alquist-Priolo Zoned Faults in the East Bay Area**



Source: Landsat 1985; CW Jennings 1994; Alquist-Priolo 2002

0 0.375 0.75 1.5 2.25 3 Miles

0 0.375 0.75 1.5 2.25 3 Kilometers

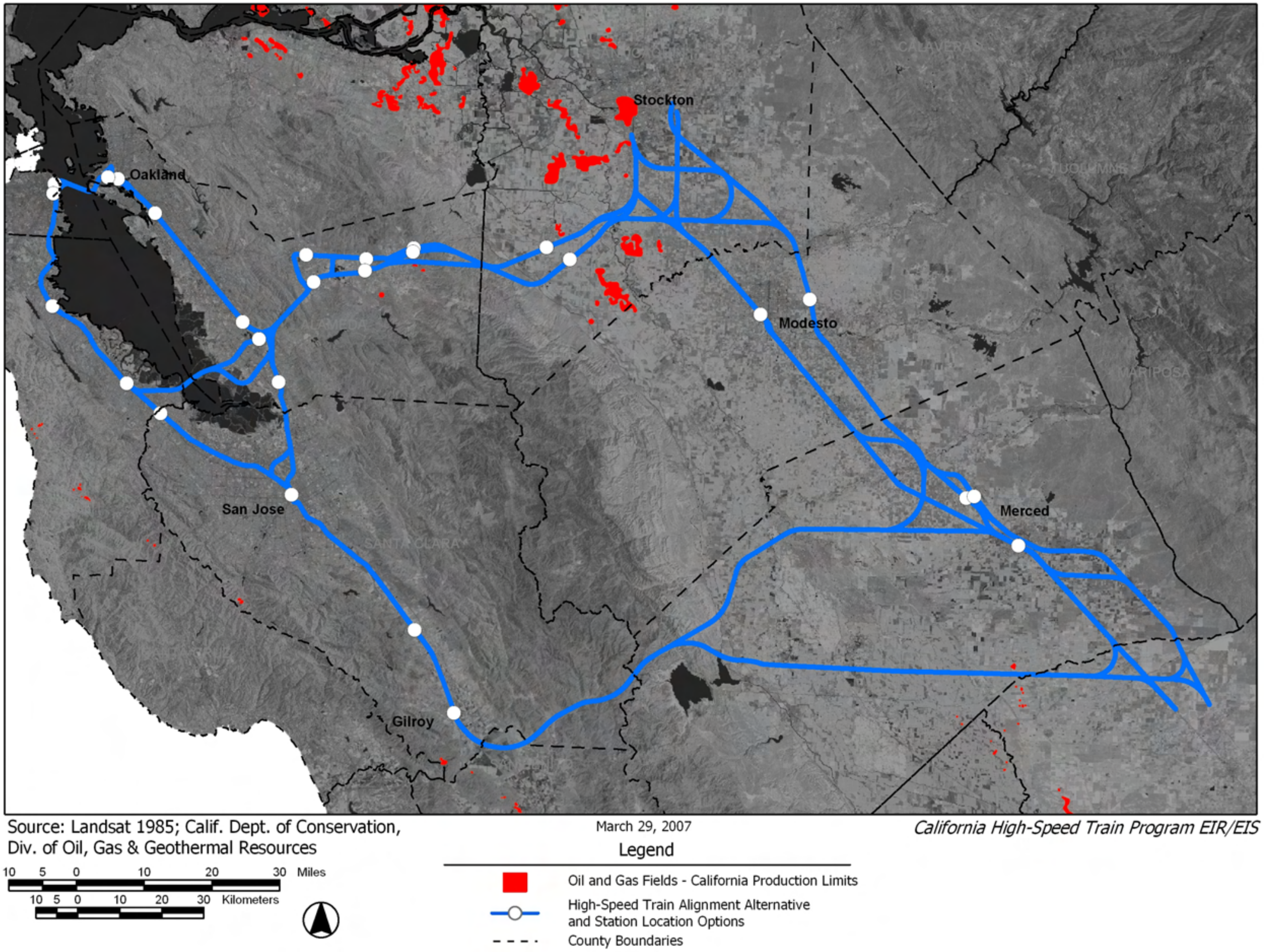
**Legend**

- Alquist-Priolo Earthquake Fault Zones
- Quaternary (and Historical) Faults
- Calaveras Fault
- Aerial/Structure
- Retained Fill
- Cut & Fill/At Grade
- Embankment
- Tunnel
- Trench

FLY CALIFORNIA
Without ever leaving the ground

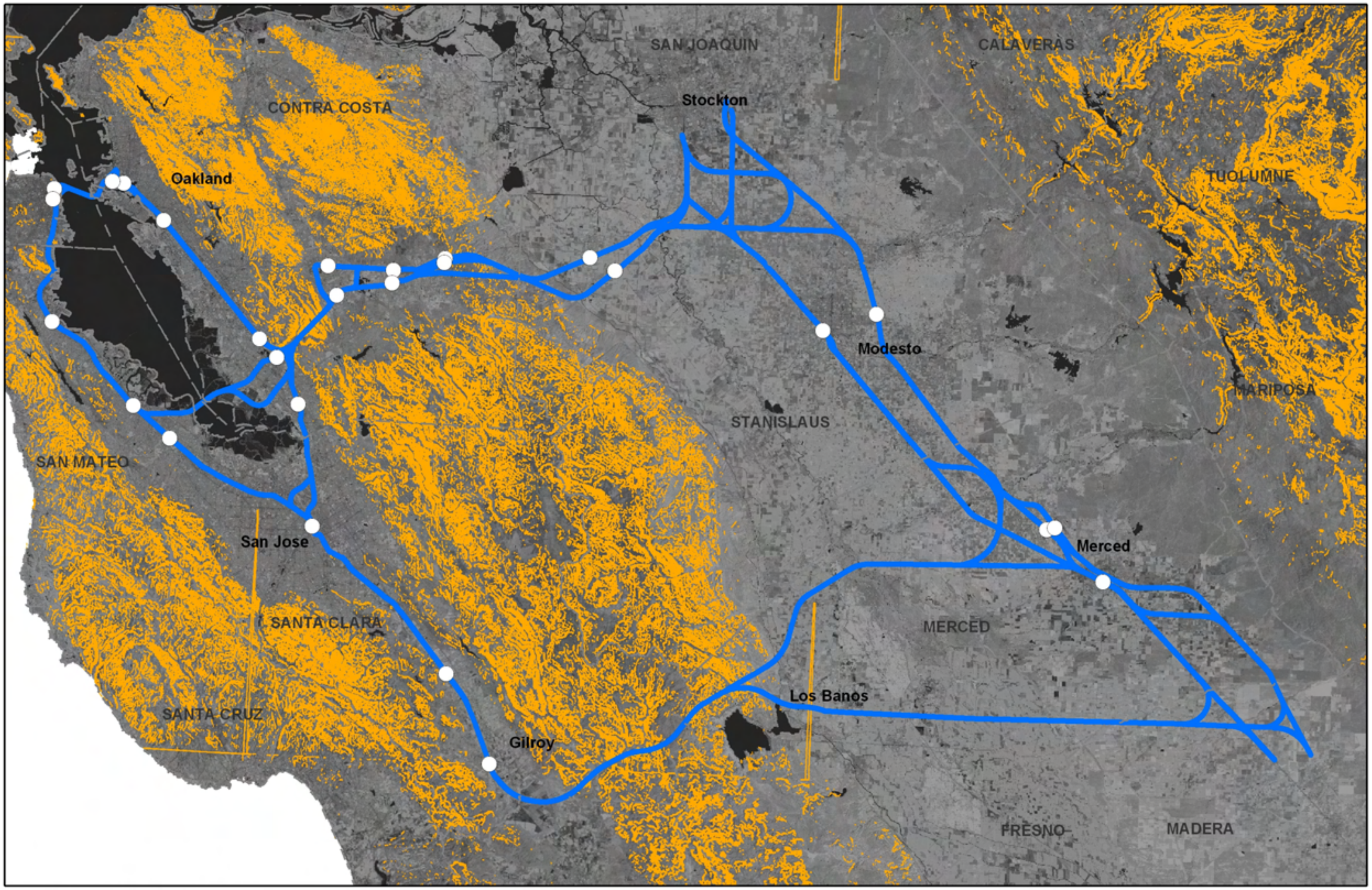
U.S. Department of Transportation
**Federal Railroad Administration**

**Figure 3.13-4c**
**Quaternary Faults and Alquist-Priolo Zoned Faults in the Calaveras Fault Area**




U.S. Department
of Transportation
**Federal Railroad**
**Administration**

**Figure 3.13-5**
**Oil and Gas Fields in the Study Region**




Source: Landsat 1985; USGS
Digital Elevation Model (DEM)

10 5 0 10 20 30 Miles

10 5 0 10 20 30 Kilometers

March 29, 2007

Legend

Slopes steeper than 33% (within study area)

High-Speed Train Alignment Alternative and Station Location Options

County Boundaries

*California High-Speed Train Program EIR/EIS*



**Figure 3.13-6**
**Areas of Unstable Slopes in the Study Region**

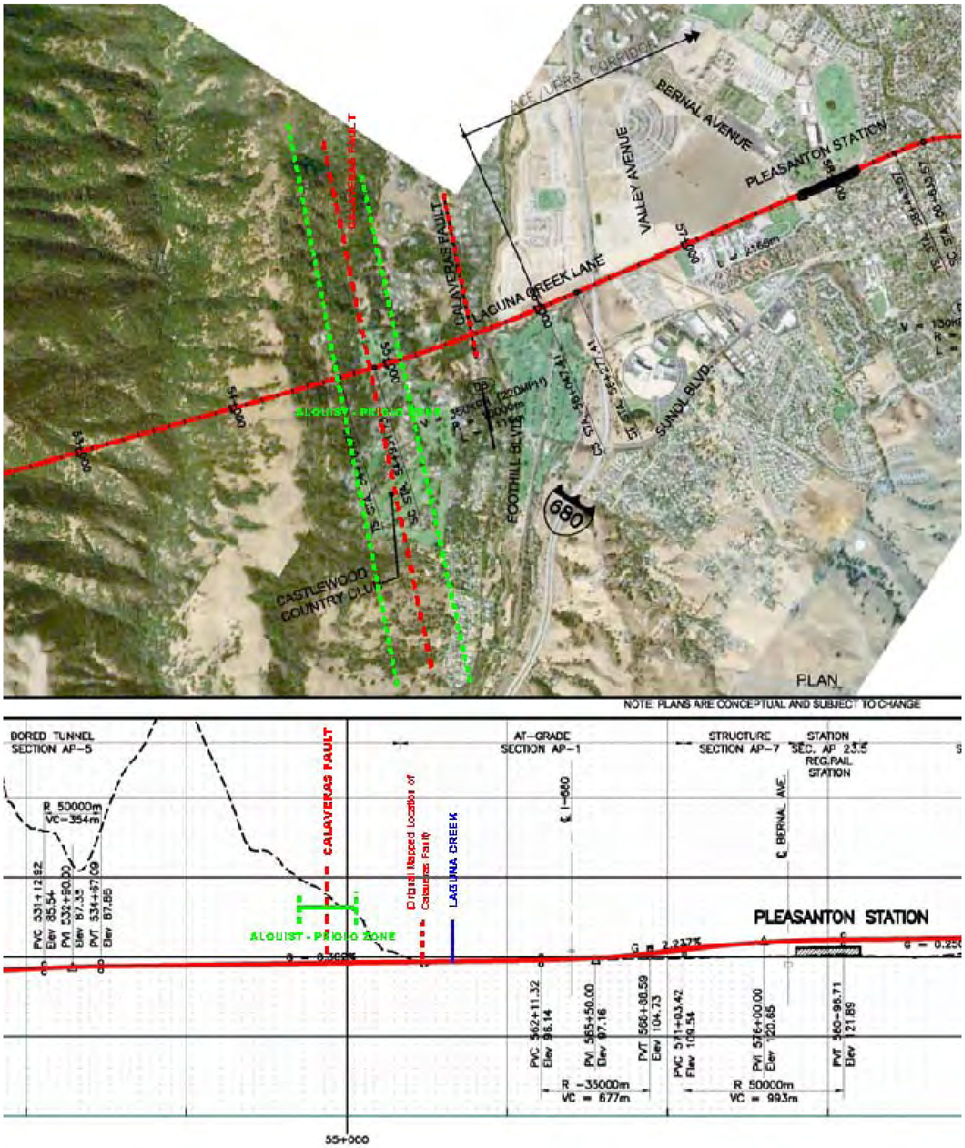





**Figure 3.13-7**
**Revised Calaveras Fault Location**

whenever possible. These objectives have been carried through the development of the HST Alignment Alternatives for the Bay Area to Central Valley Region.

FRA and the Authority discovered that the location of the Calaveras Fault was incorrectly shown in the Draft Program EIR/EIS. Thus, as proposed, the Altamont Alignment alternative would cross the actual fault line in tunnel. Addressing additional safety issues for crossing the fault in tunnel would require additional design work, or meeting the Authority's objective of crossing major fault zones at grade would require redesign and realignment of the Altamont Alignment alternatives and would result in increased environmental impacts, as well as increased travel times for the Altamont alignment alternatives.

Any impacts that remain at the conclusion of project-level environmental review would be mitigated through specific design and construction practices described in the following mitigation section.

### 3.13.5 Mitigation Strategies and CEQA Significance Conclusions

Based on the analysis above, and considering the CEQA thresholds of significance for geology and soils, all HST Alignment Alternatives would have less-than-significant geology and soils impacts related to: (1) access to mineral resources and other geologic features with potential scientific values and (2) the potential to create hazardous conditions from the release of gases into subsurface facilities.

The analysis indicates that significant impacts before mitigation are likely for some alignment alternatives related to (1) difficult excavation, (2) seismic hazards from ground motion and liquefaction, (3) active fault crossings, and (4) slope instability.

Without mitigation, significant impacts with respect to difficult excavation are anticipated for the Patterson Pass and UPRR alignment segments crossings of the Diablo Range, and the Niles to Sunol tunnel segment in the East Bay to Central Valley corridor, and for the Gilroy to San Luis Reservoir segment for the Pacheco Pass alternative. Significant slope instability impacts prior to mitigation are also anticipated for each of these segments, where they are not in tunnel.

Significant seismic hazards prior to mitigation are anticipated for the (1) San Francisco and San Jose corridor, (2) the Oakland to San Jose corridor, (3) the Pacheco Pass alternative between San Jose and the Central Valley floor, (4) the East Bay to Central Valley corridor, and (5) the San Francisco Bay Crossings. Each of these alternatives is potentially subject to strong ground shaking throughout the entire length of their alignments. The most significant hazard would be associated with the tunnel crossing of the Calaveras Fault for the East Bay to Central Valley corridor.

In addition, locally they are subject to liquefaction induced ground failure and active or potentially active fault crossings are present along the alternatives in each of these corridors.

This document contains a broad program analysis that generally identifies the locations of potential geologic impact areas of the proposed HST Alignment Alternatives. These are areas that would need further study in environmental documentation at the project level.

Mitigation of potential impacts related to geologic and soils conditions must be developed on a site-specific basis, based on the results of more detailed (design-level) geologic and geotechnical engineering studies. Consequently, geologic and geotechnical mitigation would be identified in subsequent, project-level analysis rather than at the program level. Following is an overview of general approaches to possible geologic and geotechnical mitigation.

A. SEISMIC HAZARDS

The potential for traffic safety issues related to ground shaking during a large earthquake cannot be mitigated completely; this holds true for most vehicle transportation systems throughout California. However, some strategies are available to reduce hazards, including the following:

- Design structures to withstand anticipated ground motion, using design options such as redundancy and ductility.
- Design and engineer all structures for earthquake activity using Caltrans Seismic Design Criteria.
- Prevent liquefaction and seismically induced settlement, and the resulting structural damage and traffic hazard impacts, using soil densification techniques such as preloading, stone columns, deep dynamic compaction or grouting.
- Design and install foundations resistant to soil liquefaction and settlement, e.g. deep foundations
- Utilize motion-sensing instruments to provide ground motion data and a control system to temporarily shut down HST operations during or after an earthquake to reduce risks.
- Apply Section 19 requirements from the most current Caltrans Standard Specifications to ensure geotechnically stable slopes are planned and created, using buttress berms, flattened slopes, drains, and/or tie-backs in areas of potential seismically induced slope instability.

B. FAULT CROSSINGS—SURFACE RUPTURE

The potential for ground rupture along active faults is one of the few geologic hazards that rarely can be fully mitigated. However, known active faults are typically monitored, and in some cases fault creep is mitigated with routine maintenance, which could include repaving or minor track re-alignment. Project design could provide for the installation of early warning systems triggered by strong ground motion associated with ground rupture. Linear monitoring systems such as time domain reflectometers (TDRs) could be installed along major highways and rail lines within the zone of potential ground rupture. These devices emit electronic information that is processed in a centralized location and could be used to temporarily control traffic and trains, thus reducing accidents. In addition, the HST project has been modified in mountain crossing areas where tunnels are proposed to avoid crossing known or mapped active faults within the tunnel. A tunnel crossing was proposed due to land use, environmental, and topographic conditions, but subsequently corrected information indicated that the tunnel as proposed would cross the Calaveras Fault.

The following mitigation strategies can be refined and applied at the project-specific level and will reduce this impact:

- Install early warning systems triggered by strong ground motion associated with ground rupture, such as linear monitoring systems (TDRs) along major highways and rail lines within the zone of potential rupture to provide early warnings and allow temporary control of rail and automobile traffic to avoid and reduce risks.
- Avoid active faults to the extent possible. Where avoidance is not possible, cross active faults at grade and perpendicular to the fault line, whenever possible. Where tunnel use is necessary across an active fault, assure safety through advanced tunnel design and fire/life/safety systems, or pursue further design and alignment variations to allow crossing at grade or on aerial structures.

C. SLOPE STABILITY/LANDSLIDES

- The potential for failure of natural and temporary construction slopes and retention structures can be mitigated through geotechnical investigation and review of proposed earthwork and foundation excavation plans and profiles. Based on investigation and review, recommendations would be provided for temporary and permanent slope reinforcement and protection, as needed. These recommendations would be incorporated into the construction plans. Additionally, during construction, geotechnical inspections will be performed to verify that no new, unanticipated conditions are encountered and to verify the proper incorporation of recommendations. Slope monitoring may also be incorporated into the final design where warranted.

The following mitigation strategies can be refined and applied at the project-specific level and will reduce this impact:

- Install temporary and permanent slope reinforcement and protection, based on geotechnical investigations and review of proposed earthwork and foundation excavation plans.
- Apply Section 19 requirements from the most current Caltrans Standard Specifications to ensure geotechnically stable slopes are planned and created, using buttress berms, flattened slopes, drains, and/or tie-backs in areas of potential slope instability.
- Conduct geotechnical inspections during construction to verify that no new, unanticipated conditions are encountered
- Incorporate slope monitoring into final design.

D. AREAS OF DIFFICULT EXCAVATION

The potential for difficult excavation in areas of hard rock and faults cannot be fully mitigated, but it can be anticipated so that safety is ensured, potential environmental impacts are addressed, and project schedule problems are avoided to the extent possible. This includes focusing future geotechnical engineering and geologic investigations in these areas and incorporating the findings into project construction documents, communicating with the contractors during the bid process, and monitoring actual conditions during and after construction.

The following mitigation strategies can be refined and applied at the project-specific level and will reduce this impact:

- Identify areas of potentially difficult excavation to ensure safe practices.
- Focus future geotechnical engineering and geologic investigations in areas of potentially difficult excavation.
- Monitor conditions during and after construction.
- Based on geologic and geotechnical investigations, incorporate appropriate tunnel excavation and lining techniques in the project design to ensure safety.

E. HAZARDS RELATED TO OIL AND GAS FIELDS

Hazards related to potential migration of hazardous gases attributable to the presence of oil fields, gas fields, or other subsurface sources can be mitigated by following strict federal and state Occupational Safety & Health Administration (OSHA/CalOSHA) regulatory requirements for excavations, and consulting with other agencies, such as the Department of Conservation (Division of Oil and Gas) and the Department of Toxic and Substances Control, as appropriate, regarding known areas of concern. Mitigation measures would include using safe and explosion-proof equipment during construction and testing for gases regularly. Active monitoring systems and alarms would be required in underground construction areas and facilities where subsurface gases are present. Gas barrier systems have also been used effectively for subways in the Los Angeles area. Installing gas detection systems can monitor the effectiveness of these systems.

The following mitigation strategies can be refined and applied at the project-specific level and will reduce this impact:

- Follow federal and state OSHA/CalOSHA regulatory requirements for excavations.
- Consult with other agencies, such as the Department of Conservation's Division of Oil and Gas and the Department of Toxic Substances Control, regarding known areas of concern.
- Use safe and explosion-proof equipment during construction.
- Test for gases regularly.
- Install monitoring systems and alarms in underground construction areas and facilities where subsurface gases are present.
- Install gas barrier systems or gas collection systems and passive or active gas venting systems in areas where subsurface gases are identified

F. MINERAL RESOURCES

In some cases, mineral resources sites may represent valuable sources of materials that either should be completely developed prior to use for another purpose or should be avoided by proposed facilities to the extent feasible. This practice could result in realignment and/or proposed relocation or modification of other proposed facilities. To mitigate the potential for significant project redesign, important mineral sites should be identified as early as possible.

The above mitigation strategies are expected to reduce the geologic and soils impacts of the HST Alignment Alternatives to a less-than-significant level. Additional environmental assessment will allow a more precise evaluation in the second-tier, project-level environmental analyses.

<u>Subsequent Analysis</u>

As described in Method of Evaluation of Impacts above, this analysis was performed generally on the basis of existing data available in GIS format. The data provided in this section are intended for planning purposes, are not meant to be definitive for specific sites, and have not been independently confirmed. More detailed geologic/geotechnical studies would be required at the project level and likely would include subsurface exploration, laboratory testing, and engineering analyses to support detailed alignment design and mitigation of potential impacts associated with geologic and soils conditions, including seismic hazards, slope stability, areas of difficult excavation, areas of potential oil and gas along proposed tunnel alignments, and mineral resources. In addition, the detailed geologic/geotechnical studies should address expansive and corrosive soils.