

CALIFORNIA HIGH-SPEED TRAIN

Project Environmental Impact Report /
Environmental Impact Statement

DRAFT

Geology, Soils, and Seismicity Technical Report

Merced to Fresno Section
Project EIR/EIS

August 2011



DRAFT
TECHNICAL REPORT

Merced to Fresno Section
**Geology, Soils, and
Seismicity**

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List of Abbreviated Terms

Acronym/ Abbrev.	Title
AASHTO	American Association of State Highway and Transportation Officials
AREMA	American Railway Engineers and Maintenance-of-Way Association
ASCE	American Society of Civil Engineers
ASTM	ASTM International [formerly known as American Society for Testing and Materials]
Authority	California High-Speed Rail Authority
bgs	below ground surface
BMPs	best management practices
Caltrans	California Department of Transportation
CBC	California Building Code
CDC	California Department of Conservation
CDSM	cement deep soil mixing
CEQA	California Environmental Quality Act
CGS	California Geological Survey
CIDH	cast-in-drill hole
DOGGR	Division of Oil, Gas, and Geothermal Resources
EIR/EIS	Environmental Impact Report/ Environmental Impact Statement
FRA	Federal Railroad Administration
g	acceleration due to gravity
HMF	heavy maintenance facility
HST	high speed train
IBC	International Building Code
ka	thousand years ago
LFRD	Load and Resistance Factor Design
Ma	million years ago
MCE	maximum credible earthquake
MF	Modesto Formation
mph	miles per hour
MRZ	mineral resource zone
NAVD 88	North American Vertical Datum of 1988
NEPA	National Environmental Policy Act
NRCS	Natural Resources Conservation Service

Acronym/ Abbrev.	Title
P-C	production-consumption
RF	Riverbank Formation
SR	State Route
USGS	United States Geological Survey

Glossary

Active faults: Faults that have moved in the last 11,000 years or so. See **fault** definition below.

Aggregate: Construction material consisting of alluvial sand and gravel or crushed stone that meets standard specifications for use in Portland cement concrete or asphalt concrete or in engineered fills.

Alignment: The horizontal route of a transportation corridor or path.

Alluvium: Sedimentary materials deposited by running water.

Alquist-Priolo Earthquake Fault Zoning Act: California law passed in 1972 to prevent construction of buildings used for human occupancy on surface traces of active faults.

Ash: The smallest tephra fragments that can travel hundreds to thousands of miles downwind from a volcano.

Colluvium: A general term applied to unconsolidated material deposited by rainwash or slow continuous downslope creep, usually collecting at the base of slopes or hillsides.

Corrosivity: Potential for a soil to corrode buried materials (concrete, uncoated steel).

Eolian: Wind-blown deposits

Erodibility: Potential for a soil to be eroded, either by wind or water.

Fault: A fracture in the earth's lithosphere (brittle rocky shell) along which movement has occurred. The relative movement can be predominantly horizontal, vertical, or inclined.

Fault class: Class A is defined as having geologic evidence demonstrating the existence of Quaternary fault of tectonic origin, whether the fault is exposed by mapping or inferred from liquefaction or other deformation features. Class B is defined as having geologic evidence demonstrating the existence of Quaternary deformation, but either (1) the fault might not extend deeply enough to be a potential source of earthquakes, or (2) currently available geologic evidence is too strong to confidently assign the feature Class C but not strong enough to assign it Class A (United States Geological Survey [USGS] 2009b).

Fault creep: Slow, more or less continuous movement occurring on faults due to ongoing tectonic deformation. Faults that are creeping do not tend to have large earthquakes.

Fault zone: A group of fractures in soil or rock where there has been displacement of the two sides relative to one another. A fault zone ranges from a few feet to several miles wide.

Geomorphology: The science concerned with understanding the surface of the Earth and the processes by which it is shaped, both past and present.

Groundwater: Water contained and transmitted through open spaces within rock and sediment below the ground surface.

Holocene: Geologic time period that covers approximately the past 11,000 years to the present.

Lag gravel: A surface accumulation of coarse gravel produced by the removal of finer particles.

Landslide: Movement of earth slopes due to the forces of gravity or seismic loading. Landslides can occur in rock or soil and on shallow or steep slopes depending on the combination of gravity forces, seismic forces, water pressure, and soil or rock strength.

Land subsidence: Loss of surface elevation due to removal of subsurface support. A common cause of land subsidence has been groundwater or petroleum withdrawal.

Liquefaction: A type of ground failure in which soils lose their strength as a result of build-up in pore-water pressure during and immediately following ground shaking.

Maximum credible earthquake: The largest hypothetical earthquake reasonably capable of occurring based on current geological knowledge. The maximum credible earthquake (MCE) differs from the Maximum Considered Earthquake (MCE) used in code documents such as American Society of Civil Engineers (ASCE) 7. Caltrans defines the MCE as the largest hypothesized earthquake reasonably capable of occurring, based on current geological knowledge. The current use of MCE in code documents refers to an earthquake with a 2% probability of exceedance in 50 years. The same initials for the maximum considered and the maximum credible earthquake can result in some confusion.

Mineral Resource Zone (MRZ)-1: Area where adequate information indicates that no significant mineral deposits are present or where it is judged that little likelihood exists for their presence.

MRZ-2: Area where adequate information indicates significant mineral deposits are present, or where it is judged that a high likelihood exists for their presence.

Permitted aggregate resources: Aggregate deposits that have been determined to be acceptable for commercial use, exist within properties owned or leased by aggregate-producing companies, and have permits allowing mining of aggregate material. These are also called "reserves".

Physiography: The processes and patterns in the natural environment, which includes geomorphology.

Potentially active fault: Faults that have shown movement between the last 11,000 to 1.6 million years and meet the criteria of sufficiently active and well-defined.

Production-consumption region: The market area of a commodity.

Quaternary: A subdivision of geologic time that covers approximately the past 1.6 million years to the present time. The Quaternary time period includes the Holocene time period.

Seiche: Oscillation or "sloshing" of water in a lake, bay, or other enclosed body as a result of landsliding or seismic ground shaking.

Seismic loading: The force of an earthquake on a structure or in soil.

Soil shrink-swell potential: The potential of a soil to expand and contract with wetting and drying cycles, also called expansion potential.

Sufficiently active fault: A fault that shows evidence of Holocene surface displacement that may be directly observable or inferred.

Surface fault rupture: Occurs when movement on a fault deep within the earth breaks through the surface.

Topography: The shape and features of the natural surface of the earth.

Tsunami: A wave that travels in the open ocean and is caused by an undersea earthquake, landslide, or volcanic activity.

Well-defined fault: A fault that is clearly detectable by a trained geologist as a physical feature at or just below the ground surface. The fault may be identified by direct observation or by indirect methods (e.g., geomorphic evidence, geophysical surveys, etc.).

Wetland: An area that is regularly saturated by surface water or groundwater and is characterized by a prevalence of vegetation that is adapted for life in saturated soil conditions.

1.0 Introduction

The California High-Speed Train (HST) System, as shown in Figure 1-1, is planned to provide intercity, high-speed service on more than 800 miles of tracks throughout California, connecting the major population centers of Sacramento, the San Francisco Bay Area, the Central Valley, Los Angeles, the Inland Empire, Orange County, and San Diego. The HST System is envisioned as a state-of-the-art, electrically powered, high-speed, steel-wheel-on-steel-rail technology, which will include contemporary safety, signaling, and automated train-control systems. The trains will be capable of operating at speeds of up to 220 miles per hour (mph) over a fully grade-separated, dedicated track alignment.

Two phases of the California HST System are planned. Phase 1 will connect San Francisco to Los Angeles via the Pacheco Pass and the Central Valley. An expected express trip time between San Francisco and Los Angeles is mandated to be 2 hours and 40 minutes or less. Phase 2 will connect the Central Valley to the state's capital, Sacramento, and will extend the system from Los Angeles to San Diego.

The California HST System will be planned, designed, constructed, and operated under the direction of the California High-Speed Rail Authority (Authority), a state governing board formed in 1996. The Authority's statutory mandate is to develop a high-speed rail system that is coordinated with the state's existing transportation network, which includes intercity rail and bus lines, regional commuter rail lines, urban rail and bus transit lines, highways, and airports.

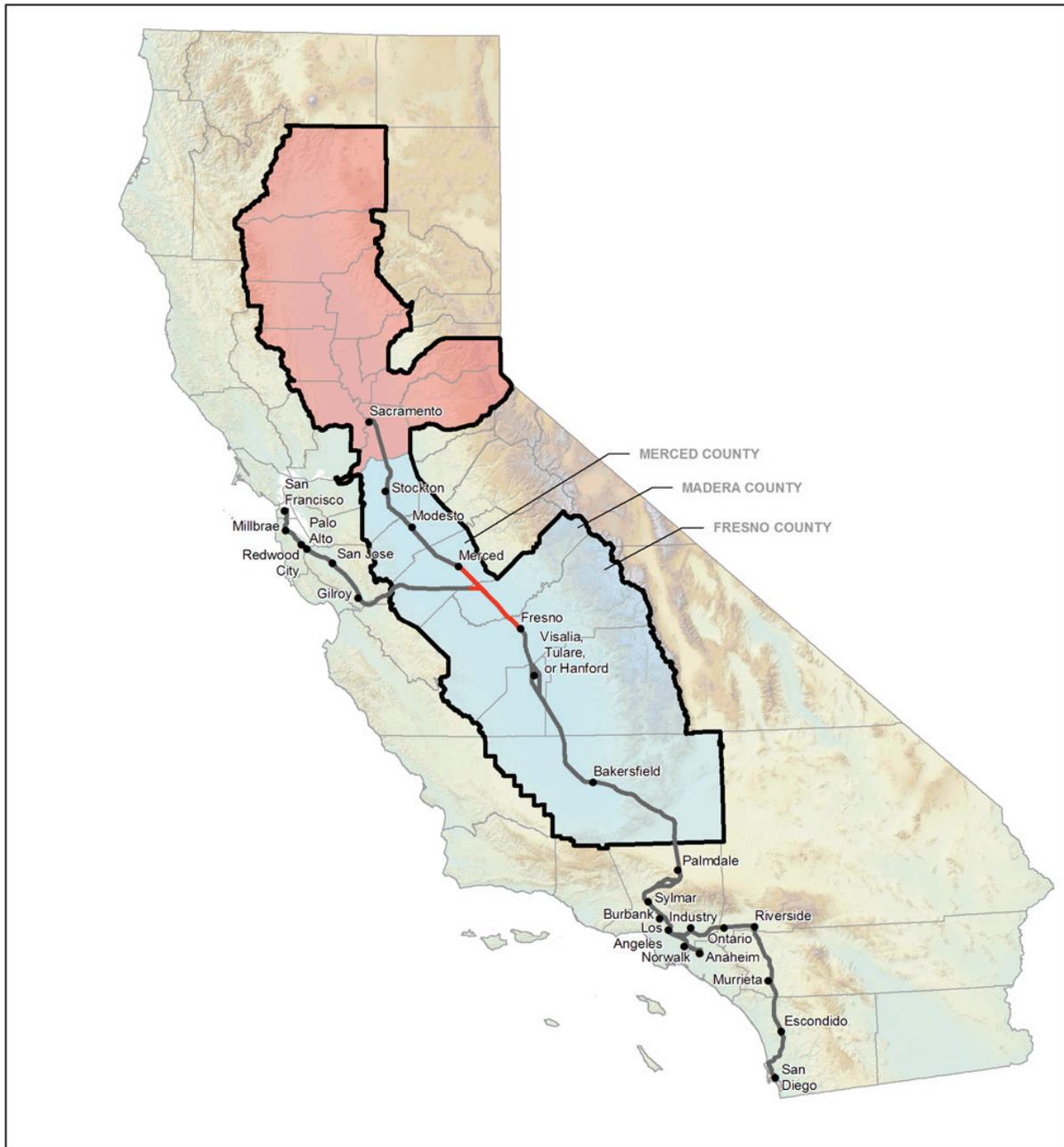
Definition of HST System

The system that includes the HST tracks, structures, stations, traction power substations, and maintenance facilities and train vehicles able to travel 220 mph.

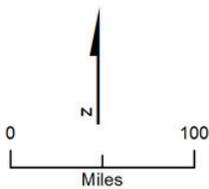
The Merced to Fresno HST Section is a critical Phase 1 link connecting the Bay Area HST sections to the Fresno to Bakersfield, Bakersfield to Palmdale, and Palmdale to Los Angeles HST sections. The Merced to Fresno Section alternatives originated in two program Environmental Impact Report/Environmental Impact Statement (EIR/EIS) documents. The Authority and the Federal Railroad Administration (FRA) prepared the 2005 *Final Program EIR/EIS for the Proposed California High-Speed Train System EIR/EIS* (Statewide Program EIR/EIS) (Authority and FRA 2005) and the 2008 *Bay Area to Central Valley HST Final Program EIR/EIS* (Bay Area to Central Valley Program EIR/EIS) (Authority and FRA 2008) to evaluate the ability of an HST system to meet the existing and future capacity demands on California's intercity transportation system and to identify a preferred alignment for the San Francisco Bay Area (Bay Area) to Central Valley sections of the HST System, respectively.

This technical report has been prepared in support of the Project EIR/EIS prepared for the Merced to Fresno Section of the proposed California HST System. This technical report provides support and detailed analysis of geology, soils, and seismicity related to the No Project Alternative and the HST alternatives. Section 2 of this report provides a project description. Section 3 describes the affected environment (i.e., existing conditions), and Section 4 evaluates the range of possible impacts of each alternative. Section 5 describes measures to avoid, minimize, or, if necessary, mitigate impacts of the HST alternatives on or from geology, soils, and seismicity. Sections 6 and 7 summarize impacts according to federal and state guidelines, respectively. Sections 8 and 9 provide references and the qualifications of the preparers of this document, respectively. The analysis is based on an approximate 15% design of the HST alternatives and has been conservatively estimated to quantify and qualify impacts.

The 2005 *Final Program Environmental Impact Report/Environmental Impact Statement for the Proposed California HST System* (Authority and FRA 2005) concluded that the project would have a low potential for impacts due to prevailing geology, soils, and seismicity because these impacts are considered as part of design; and the Program EIR/EIS committed to design practices and strategies to mitigate most, if not all potential impacts.



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- Merced to Fresno Section
- Statewide HST System
- Potential Station
- ▭ Counties Commonly Associated with the Central Valley
- ▭ Sacramento Valley
- ▭ San Joaquin Valley

Figure 1-1
 HST System in California

The Authority has identified design standards and design measures for both the construction and the operational phases of the project to address the identified risks related to geology, soils, and seismicity. The design standards include guidelines and code requirements published by the American Association of State Highway and Transportation Officials (AASHTO), the American Railway Engineers and Maintenance-of-Way Association (AREMA), the California Department of Transportation (Caltrans), and the International Building Code (IBC). The key references that will be used for design are listed in Section 3.3.4, Design Standards and Guidelines, and Section 5, Standard Engineering and Design Measures Incorporated as Part of the HST Project. These design standards and best management practices (BMPs) have been successful in minimizing risk of impacts related to geology, soils, and seismicity under similar conditions, including the operation of HST systems in seismically active areas besides California in such places as Japan and Taiwan. Similar successful performance would be expected for the California HST System, as long as the risks from geology, soils, and seismicity are adequately defined and appropriate engineering design measures are implemented.

The following topics were omitted from this geology, soils, and seismicity report because they do not present a risk in the Merced to Fresno Section:

- Seiche and tsunami hazards, because the Merced to Fresno Section of the HST System is not located close to a lake, bay, or ocean that might create these risks.
- Volcanic hazards, because the nearest volcanic source is more than 85 miles from the study area. Although ash fall from volcanic activity could occur within the study area, there is less than a 1% probability of a volcanic eruption from the closest source to the project during any given year (Hill et al. 2004), and the predominant direction of ash fall would be to the east, if a volcanic event were to occur. This combination of low activity and predominant wind direction makes this event too unlikely to be a hazards consideration.
- Subsurface gas hazards, because no part of the project includes tunneling or substantial subsurface earthwork that would take place in a confined condition.

Construction of this project requires substantial quantities of borrow material for use as track ballast and subgrade materials, in approach fills for elevated structures, and for aggregate in concrete construction. The Authority and FRA evaluated borrow requirements for the project and identified six permitted and operating aggregate quarries in the state with capacity for ballast and have determined that adequate borrow sources exist for project construction without harmfully depleting available sources. The locations of these borrow sites are discussed in (PMT reference). Based on the Authority's and FRA's evaluations, borrow sites are not evaluated in the analysis of geology, soils, and seismicity.

Construction of this project requires substantial quantities of borrow material for use as track ballast and subgrade materials in approach fills for elevated structures and for aggregate in concrete construction. The Office of Mine Reclamation (California Department of Conservation [CDC]) provided a list of quarries within the state of California (CDC 2010). The Merced to Fresno Section of the HST project would require, depending on the HST alternative, approximately 1,675,000 to 2,700,000 tons of aggregate and 680,000 to 1,000,000 cubic yards of fill (assuming no fill is provided by project excavation). Borrow requirements for the project were evaluated and five permitted and operating aggregate quarries were identified in California with capacity for ballast. Figure 1-2 shows the location of these quarries. U.S. Geological Survey (USGS) surveys concluded that there were 196 million tons of aggregate permitted for mining within the San Joaquin Valley air basin in 2001. USGS estimated that this represents only about 6% of the resource (California Geological Survey [CGS] 2006). Based on this estimate, there would be sufficient aggregate and fill available in the air basin to provide material for the project without harmfully depleting available sources; therefore, borrow sites are not evaluated in the analysis of geology, soils, and seismicity.



Source: CDC (2010), CARB (2004).

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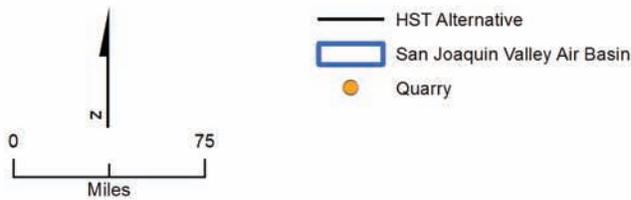


Figure 1-2
 Location of Rock Quarries

2.0 Project Description

The purpose of the Merced to Fresno Section of the HST Project is to implement the California HST System between Merced and Fresno, providing the public with electric-powered high-speed rail service that provides predictable and consistent travel times between major urban centers and connectivity to airports, mass transit systems, and the highway network in the south San Joaquin Valley, and to connect the northern and southern portions of the HST system. The approximately 65-mile-long corridor between Merced and Fresno is an essential part of the statewide HST System. The Merced to Fresno Section is the location where the HST would intersect and connect with the Bay Area and Sacramento branches of the HST System; it would provide a potential location for the heavy maintenance facility (HMF) where the HSTs would be assembled and maintained, as well as a test track for the trains; it would also provide Merced and Fresno access to a new transportation mode and would contribute to increased mobility throughout California.

2.1 No Project Alternative

The No Project Alternative refers to the projected growth planned for the region through the 2035 time horizon without the HST Project and serves as a basis of comparison for environmental analysis of the HST build alternatives. The No Project Alternative includes planned improvements to the highway, aviation, conventional passenger rail, and freight rail systems in the Merced to Fresno project area. There are many environmental impacts that would result under the No Project Alternative.

2.2 High-Speed Train Alternatives

As shown in Figure 2-1, there are three HST alignment alternatives proposed for the Merced to Fresno Section of the HST System: the UPRR/SR 99 Alternative, which would primarily parallel the UPRR railway; the BNSF Alternative, which would parallel the BNSF railway for a portion of the distance between Merced and Fresno; and the Hybrid Alternative, which combines features of the UPRR/SR 99 and BNSF alternatives. In addition, there is an HST station proposed for both the City of Merced and the City of Fresno, there is a wye connection (see text box on page 2-3) west to the Bay Area, and there are five potential sites for a proposed HMF.

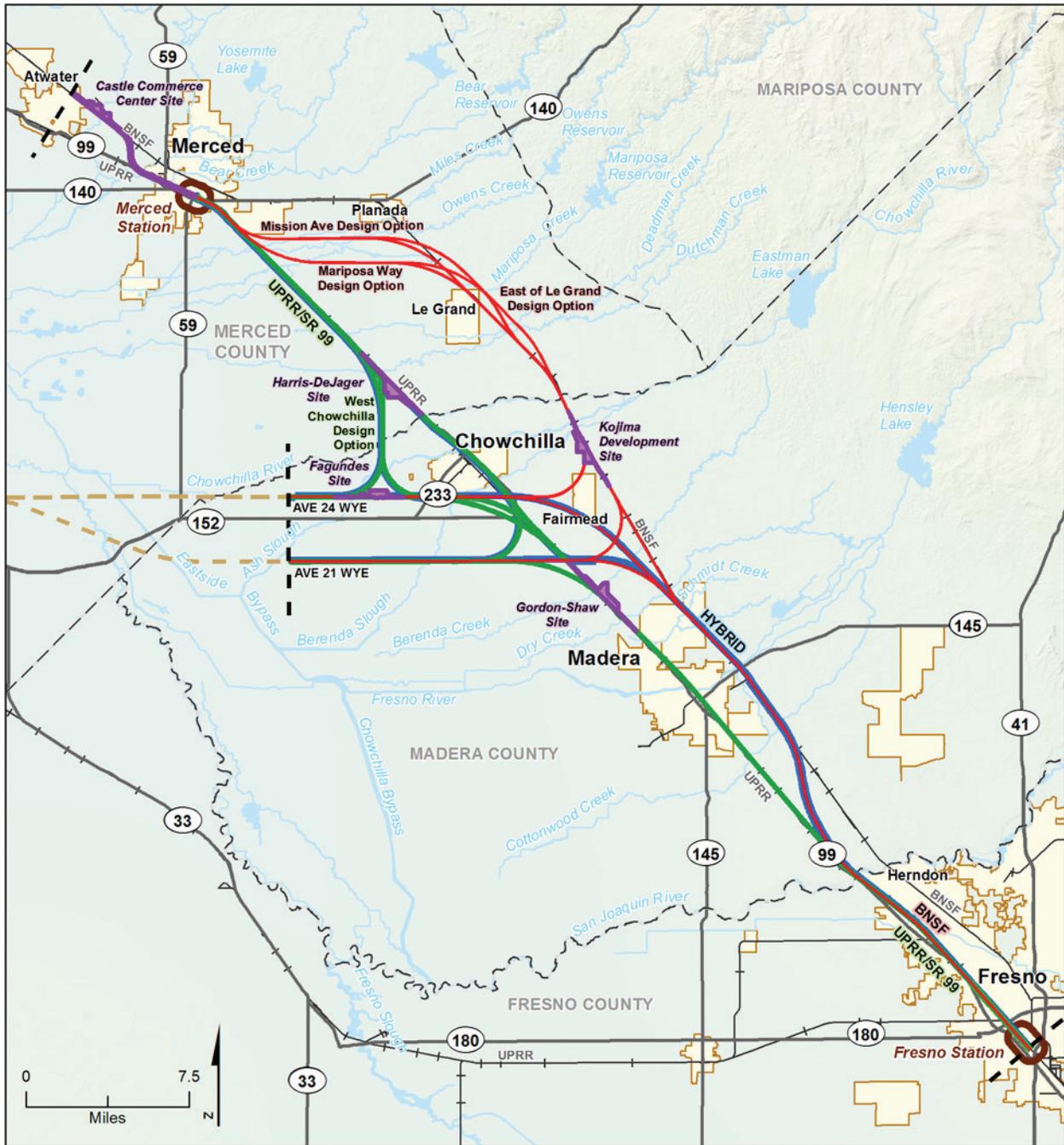
2.2.1 UPRR/SR 99 Alternative

This section describes the UPRR/SR 99 Alternative, including the Chowchilla design options, wyes, and HST stations.

2.2.1.1 North-South Alignment

The north-south alignment of the UPRR/SR 99 Alternative would begin at the HST station in Downtown Merced, located on the west side of the UPRR right-of-way. South of the station and leaving Downtown Merced, the alternative would be at-grade and cross under SR 99. Approaching the City of Chowchilla, the UPRR/SR 99 Alternative has two design options: the East Chowchilla design option, which would pass Chowchilla on the east side of town, and the West Chowchilla design option, which would pass Chowchilla 3 to 4 miles west of the city before turning back to rejoin the UPRR/SR 99 transportation corridor. These design options would take the following routes:

- **East Chowchilla design option:** This design option would transition from the west side of the UPRR/SR 99 corridor to an elevated structure as it crosses the UPRR railway and N Chowchilla Boulevard just north of Avenue 27, continuing on an elevated structure away from the UPRR corridor along the west side of and parallel to SR 99 to cross Berenda Slough. Toward the south side of Chowchilla, this design option would cross over SR 99 north of the SR 99/SR 152 interchange near Avenue 23½ south of Chowchilla. Continuing south on the east side of SR 99 and the UPRR corridor,



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- | | | |
|------------------------|--------------------------------------|--------------------|
| BNSF Alternative | Connection to Other Section | City Limit |
| UPRR/SR 99 Alternative | Station Study Area | County Boundary |
| Hybrid Alternative | Potential Heavy Maintenance Facility | Railroad |
| Project Limit | | State / US Highway |

Figure 2-1
 Merced to Fresno Section
 HST Alternatives

this design option would remain elevated for 7.1 miles through the communities of Fairmead and remain at-grade for 5.1 miles through the community of Berenda until reaching the Dry Creek crossing. The East Chowchilla design option connects to the HST sections to the west via either the Ave 24 or Ave 21 wyes (described below).

- West Chowchilla design option:** This design option would travel due south from Sandy Mush Road north of Chowchilla, following the west side of Road 11¾. The alignment would turn southeast toward the UPRR/SR 99 corridor south of Chowchilla. The West Chowchilla design option would cross over the UPRR and SR 99 east of the Fairmead city limits to again parallel the UPRR/SR 99 corridor. The West Chowchilla design option would result in a net decrease of approximately 13 miles of track for the HST System compared to the East Chowchilla design option and would remain outside the limits of the City of Chowchilla. The West Chowchilla design option connects to the HST sections to the west via the Ave 24 Wye, but not the Ave 21 Wye.

The UPRR/SR 99 Alternative would continue toward Madera along the east side of the UPRR south of Dry Creek and remain on an elevated profile for 8.9 miles through Madera. After crossing over Cottonwood Creek and Avenue 12, the HST alignment would transition to an at-grade profile and continue to be at-grade until north of the San Joaquin River. After the alternative crosses the San Joaquin River, it would rise over the UPRR railway on an elevated guideway, supported by straddle bents, before crossing over the existing Herndon Avenue and again descending into an at-grade profile and continuing west of and parallel to the UPRR right-of-way. After elevating to cross the UPRR railway on the southern bank of the San Joaquin River, south of Herndon Avenue, the alternative would transition from an elevated to an at-grade profile. Traveling south from Golden State Boulevard at-grade, the alternative would cross under the reconstructed Ashlan Avenue and Clinton Avenue overhead structures. Advancing south from Clinton Avenue between Clinton Avenue and Belmont Avenue, the HST guideway would run at-grade adjacent to the western boundary of the UPRR right-of-way and then enter the HST station in Downtown Fresno. The HST guideway would descend in a retained-cut to pass under the San Joaquin Valley Railroad spur line and SR 180, transition back to at-grade before Stanislaus Street, and continue to be at-grade into the station. As part of a station design option, Tulare Street would become either an overpass or undercrossing at the station.

2.2.1.2 Wye Design Options

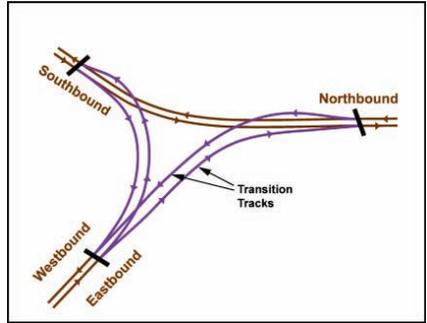
The following text describes the wye connection from the San Jose to Merced Section to the Merced to Fresno Section. There are two variations of the Ave 24 Wye for the UPRR/SR 99 Alternative because of the West Chowchilla design option. The Ave 21 Wye does not connect to the West Chowchilla design option and therefore does not have a variation.

Ave 24 Wye

The Ave 24 Wye design option would travel along the south side of eastbound Avenue 24 toward the UPRR/SR 99 Alternative and would begin diverging onto two sets of tracks west of Road 11 and west of the City of Chowchilla. Under the East Chowchilla design option, the northbound set of tracks would travel northeast across Road 12, joining the UPRR/SR 99 north-south alignment on the west side of the UPRR right-of-way just north of Sandy Mush Road. Under the West Chowchilla design option, the northbound set of tracks would travel northeast across Road 12 and would join the UPRR/SR 99 north-south alignment just south of Avenue 26. The southbound HST guideway would continue east along Avenue 24, turning south near SR 233 southeast of Chowchilla, crossing SR 99 and the UPRR railway to connect to the UPRR/SR 99 Alternative north-south

What is a "Wye"?

The word "wye" refers to the "Y"-like formation that is created where train tracks branch off the mainline to continue in different directions. The transition to a wye requires splitting two tracks into four tracks that cross over one another before the wye "legs" can diverge in opposite directions to allow bidirectional travel. For the Merced to Fresno Section of the HST System, the two tracks traveling east-west from the San Jose to Merced Section must become four tracks—a set of two tracks branching to the north and a set of two tracks branching to the south.



The diagram illustrates a wye track configuration. It shows a mainline of two tracks entering from the right, labeled 'Northbound' (top) and 'Southbound' (bottom). These tracks transition into a 'Wye' where they split into four tracks. Two tracks branch off to the left, labeled 'Westbound' (top) and 'Eastbound' (bottom). The remaining two tracks continue to the left, labeled 'Southbound' (top) and 'Northbound' (bottom). The transition area is labeled 'Transition Tracks'.

alignment on the east side of the UPRR near Avenue 21½. Under the West Chowchilla design option, the southbound tracks would turn south near Road 16 south of Chowchilla, crossing SR 99 and the UPRR to connect to the UPRR/SR 99 north-south alignment on the east side of the UPRR adjacent to the city limits of Fairmead.

Figure 2-2a shows the wye alignment for the East Chowchilla design option and Figure 2-2b shows the alignment for the West Chowchilla design option. Together, the figures illustrate the difference in the wye triangle formation for each design option connection. The north-south alignment of the West Chowchilla design option between Merced and Fresno diverges along Avenue 24 onto Road 12, on the north branch of the wye, allowing the HST alternative to avoid traveling through Chowchilla and to avoid constraining the city within the wye triangle.

Ave 21 Wye

The Ave 21 Wye would travel along the north side of Avenue 21. Just west of Road 16, the HST tracks would diverge north and south to connect to the UPRR/SR 99 Alternative, with the north leg of the wye joining the north-south alignment at Avenue 23½ and the south leg at Avenue 19½.

2.2.1.3 HST Stations

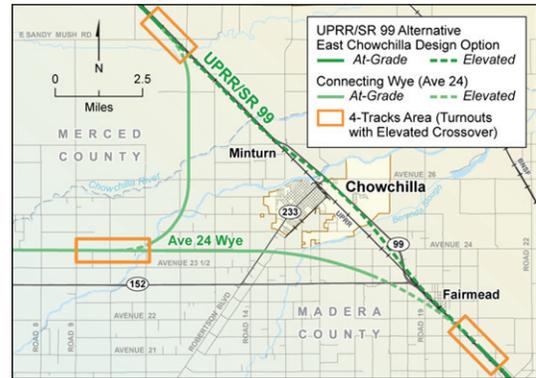
The Downtown Merced and Downtown Fresno station areas would each occupy several blocks, to include station plazas, drop-offs, a multimodal transit center, and parking structures. The areas would include the station platform and associated building and access structure, as well as lengths of platform tracks to accommodate local and express service at the stations. As currently proposed, both the Downtown Merced and Downtown Fresno stations would be at-grade, including all trackway and platforms, passenger services and concessions, and back-of-house functions.

Downtown Merced Station

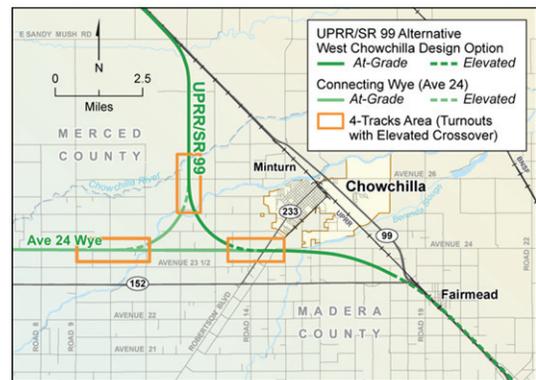
The Downtown Merced Station would be between Martin Luther King Jr. Way to the northwest and G Street to the southeast. The station would be accessible from both sides of the UPRR, but the primary station house would front 16th Street. The major access points from SR 99 include V Street, R Street, Martin Luther King Jr. Way, and G Street. Primary access to the parking facility would be from West 15th Street and West 14th Street, just one block east of SR 99. The closest access to the parking facility from the SR 99 freeway would be R Street, which has a full interchange with the freeway. The site proposal includes a parking structure that would have the potential for up to 6 levels with a capacity of approximately 2,250 cars and an approximate height of 50 feet.

Downtown Fresno Station Alternatives

There are two station alternatives under consideration in Fresno: the Mariposa Street Station Alternative and the Kern Street Station Alternative.



(a) Ave 24 Wye with the East Chowchilla Design Option



(b) Ave 24 Wye with the West Chowchilla Design Option

Figure 2-2a and b
 Ave 24 Wye and Chowchilla Design Options

Mariposa Street Station Alternative

The Mariposa Street Station Alternative is located in Downtown Fresno, less than 0.5 mile east of SR 99. The station would be centered on Mariposa Street and bordered by Fresno Street on the north, Tulare Street on the south, H Street on the east, and G Street on the west. The station building would be approximately 75,000 square feet, with a maximum height of approximately 60 feet. The two-level station would be at-grade, with passenger access provided both east and west of the HST guideway and the UPRR tracks, which would run parallel with one another adjacent to the station. Entrances would be located at both G and H Streets. The eastern entrance would be at the intersection of H Street and Mariposa Street, with platform access provided via the pedestrian overcrossing. The main western entrance would be located at G Street and Mariposa Street.

The majority of station facilities would be located east of the UPRR tracks. The station and associated facilities would occupy approximately 18.5 acres, including 13 acres dedicated to the station, bus transit center, surface parking lots, and kiss-and-ride accommodations. A new intermodal facility would be included in the station footprint on the parcel bordered by Fresno Street to the north, Mariposa Street to the south, Broadway Street to the east, and H Street to the west. The site proposal includes the potential for up to 3 parking structures occupying a total of 5.5 acres. Two of the three potential parking structures would each sit on 2 acres, and each would have a capacity of approximately 1,500 cars. The third parking structure would have a slightly smaller footprint (1.5 acres), with 5 levels and a capacity of approximately 1,100 cars. Surface parking lots would provide approximately 300 additional parking spaces.

Kern Street Station Alternative

The Kern Street Station Alternative for the HST station would also be in Downtown Fresno and would be centered on Kern Street between Tulare Street and Inyo Street. This station would include the same components and acreage as the Mariposa Street Station Alternative, but the station would not encroach on the historic Southern Pacific Railroad depot just north of Tulare Street and would not require relocation of existing Greyhound facilities. Two of the 3 potential parking structures would each sit on 2 acres and each would have a capacity of approximately 1,500 cars. The third structure would have a slightly smaller footprint (1.5 acres) and a capacity of approximately 1,100 cars. Like the Mariposa Street Station Alternative, the majority of station facilities under the Kern Street Station Alternative would be east of the HST tracks.

2.2.2 BNSF Alternative

This section describes the BNSF Alternative, including the Le Grand design options and wyes. It does not include a discussion of the HST stations, because the station descriptions are identical for each of the three HST alignment alternatives.

2.2.2.1 North-South Alignment

The north-south alignment of the BNSF Alternative would begin at the proposed Downtown Merced Station. This alternative would remain at-grade through Merced and would cross under SR 99 at the south end of the city. Just south of the interchange at SR 99 and E Childs Avenue, the BNSF Alternative would cross over SR 99 and UPRR as it begins to curve to the east, crossing over the E Mission Avenue interchange. It would then travel east to the vicinity of Le Grand, where it would turn south and travel adjacent to the BNSF tracks.

To minimize impacts on the natural environment and the community of Le Grand, the project design includes four design options:

- **Mission Ave design option:** This design option would turn east to travel along the north side of Mission Avenue at Le Grand and then would elevate through Le Grand adjacent to and along the west side of the BNSF corridor.
- **Mission Ave East of Le Grand design option:** This design option would vary from the Mission Ave design option by traveling approximately 1 mile farther east before turning southeast to cross

Santa Fe Avenue and the BNSF tracks south of Mission Avenue. The HST alignment would parallel the BNSF for a half-mile to the east, avoiding the urban limits of Le Grand. This design option would cross Santa Fe Avenue and the BNSF railroad again approximately one-half mile north of Marguerite Road and would continue adjacent to the west side of the BNSF corridor.

- **Mariposa Way design option:** This design option would travel 1 mile farther than the Mission Ave design option before crossing SR 99 near Vassar Road and turning east toward Le Grand along the south side of Mariposa Way. East of Simonson Road, the HST alignment would turn to the southeast. Just prior to Savana Road in Le Grand, the HST alignment would transition from at-grade to elevated to pass through Le Grand on a 1.7-mile-long guideway adjacent to and along the west side of the BNSF corridor.
- **Mariposa Way East of Le Grand design option:** This design option would vary from the Mariposa Way design option by traveling approximately 1 mile farther east before turning southeast to cross Santa Fe Avenue and the BNSF tracks less than one-half mile south of Mariposa Way. The HST alignment would parallel the BNSF to the east of the railway for a half-mile, avoiding the urban limits of Le Grand. This design option would cross Santa Fe Avenue and the BNSF again approximately a half-mile north of Marguerite Road and would continue adjacent to the west side of the BNSF corridor.

Continuing southeast along the west side of BNSF, the BNSF Alternative would begin to curve just before Plainsburg Road through a predominantly rural and agricultural area. One mile south of Le Grand, the HST alignment would cross Deadman and Dutchman creeks. The alignment would deviate from the BNSF corridor just southeast of S White Rock Road, where it would remain at-grade for another 7 miles, except at the bridge crossings, and would continue on the west side of the BNSF corridor through the community of Sharon. The HST alignment would continue at-grade through the community of Kismet until crossing at Dry Creek. The BNSF Alternative would then continue at-grade through agricultural areas along the west side of the BNSF corridor through the community of Madera Acres north of the City of Madera. South of Avenue 15 east of Madera, the alignment would transition toward the UPRR corridor, following the east side of the UPRR corridor near Avenue 9 south of Madera, then continuing along nearly the same route as the UPRR/SR 99 Alternative over the San Joaquin River to enter the community of Herndon. After crossing the San Joaquin River, the alignment would be the same as for the UPRR/SR 99 Alternative.

2.2.2.2 Wye Design Options

The Ave 24 Wye and the Ave 21 Wye would be the same as described for the UPRR/SR 99 Alternative (East Chowchilla design option), except as noted below.

Ave 24 Wye

As with the UPRR/SR 99 Alternative, the Ave 24 Wye would follow along the south side of Avenue 24 and would begin diverging into two sets of tracks (i.e., four tracks) beginning west of Road 17. Two tracks would travel north near Road 20½, where they would join the north-south alignment of the BNSF Alternative on the west side of the BNSF corridor near Avenue 26½. The two southbound tracks would join the BNSF Alternative on the west side of the BNSF corridor south of Avenue 21.

Ave 21 Wye

As with the UPRR/SR 99 Alternative, the Ave 21 Wye would travel along the north side of Avenue 21. Two tracks would diverge, turning north and south to connect to the north-south alignment of the BNSF Alternative just west of Road 21. The north leg of the wye would join the north-south alignment just south of Avenue 24 and the south leg would join the north-south alignment just east of Frontage Road/Road 26 north of the community of Madera Acres.

2.2.3 Hybrid Alternative

This section describes the Hybrid Alternative, which generally follows the alignment of the UPRR/SR 99 Alternative in the north and the BNSF Alternative in the south. It does not include a discussion of the HST stations because the station descriptions are identical for each of the three HST alternatives.

2.2.3.1 North-South Alignment

From north to south, generally, the Hybrid Alternative would follow the UPRR/SR 99 alignment with either the West Chowchilla design option with the Ave 24 Wye or the East Chowchilla design option with the Ave 21 Wye. Approaching the Chowchilla city limits, the Hybrid Alternative would follow one of two options:

- In conjunction with the Ave 24 Wye, the HST alignment would veer due south from Sandy Mush Road along a curve and would continue at-grade for 4 miles parallel to and on the west side of Road 11¾. The Hybrid Alternative would then curve to a corridor on the south side of Avenue 24 and would travel parallel for the next 4.3 miles. Along this curve, the southbound HST track would become an elevated structure for approximately 9,000 feet to cross over the Ave 24 Wye connection tracks and Ash Slough, while the northbound HST track would remain at-grade. Continuing east on the south side of Avenue 24, the HST alignment would become identical to the Ave 24 Wye connection for the BNSF Alternative and would follow the alignment of the BNSF Alternative until Madera.
- In conjunction with the Ave 21 Wye connection, the HST alignment would transition from the west side of UPRR and SR 99 to an elevated structure as it crosses the UPRR and N Chowchilla Boulevard just north of Avenue 27, continuing on an elevated structure along the west side of and parallel to SR 99 away from the UPRR corridor while it crosses Berenda Slough. Toward the south side of Chowchilla, the alignment (with the Ave 21 Wye) would cross over SR 99 north of the SR 99/SR 152 interchange near Avenue 23½ south of Chowchilla. It would continue to follow along the east side of SR 99 until reaching Avenue 21, where it would curve east and run parallel to Avenue 21, briefly. The alignment would then follow a path similar to the Ave 21 Wye connection for the BNSF Alternative, but with a tighter 220 mph curve. The alternative would then follow the BNSF Alternative alignment until Madera.

Through Madera and until reaching the San Joaquin River, the Hybrid Alternative is the same as the BNSF Alternative. Once crossing the San Joaquin River, the alignment of the Hybrid Alternative becomes the same as for the UPRR/SR 99 Alternative.

2.2.3.2 Wye Design Options

The wye connections for the Hybrid Alternative follow Avenue 24 and Avenue 21, similar to those of the UPRR/SR 99 and BNSF alternatives.

Ave 24 Wye

The Ave 24 Wye is the same as the combination of the UPRR/SR 99 Alternative with the West Chowchilla design option, and the Ave 24 Wye for the BNSF Alternative.

Ave 21 Wye

The Ave 21 Wye is similar to the combination of the UPRR/SR 99 Alternative with the Ave 21 Wye on the northbound leg and the BNSF Alternative with the Ave 21 Wye on the southbound leg. However, the south leg under the Hybrid Alternative would follow a tighter, 220 mph curve than the BNSF Alternative, which follows a 250 mph curve.

2.2.4 Heavy Maintenance Facility Alternatives

The Authority is studying five HMF sites (see Figure 2-1) within the Merced to Fresno Section, one of which may be selected.

- **Castle Commerce Center HMF site** – A 370-acre site located 6 miles northwest of Merced, at the former Castle Air Force Base in northern unincorporated Merced County. It is adjacent to and on the east side of the BNSF mainline, 1.75 miles south of the UPRR mainline, off of Santa Fe Drive and Shuttle Road, 2.75 miles from the existing SR 99 interchange. The Castle Commerce Center HMF would be accessible by all HST alternatives.
- **Harris-DeJager HMF site** – A 401-acre site located north of Chowchilla adjacent to and on the west side of the UPRR corridor, along S Vista Road and near the SR 99 interchange under construction. The Harris-DeJager HMF would be accessible by the UPRR/SR 99 and Hybrid alternatives if coming from the Ave 21 Wye and the UPRR/SR 99 Alternative with the East Chowchilla design option and the Ave 24 Wye.
- **Fagundes HMF site** – A 231-acre site, located 3 miles southwest of Chowchilla on the north side of SR 152, between Road 11 and Road 12. This HMF would be accessible by all HST alternatives with the Ave 24 Wye.
- **Gordon-Shaw HMF site** – A 364-acre site adjacent to and on the east side of the UPRR corridor, extending from north of Berenda Boulevard to Avenue 19. The Gordon-Shaw HMF would be accessible from the UPRR/SR 99 Alternative.
- **Kojima Development HMF site** – A 392-acre site on the west side of the BNSF corridor east of Chowchilla, located along Santa Fe Drive and Robertson Boulevard (Avenue 26). The Kojima Development HMF would be accessible by the BNSF Alternative with the Ave 21 Wye.

3.0 Affected Environment

This section of the Geology, Soils, and Seismicity Technical Report is organized to discuss the source of information, regulatory setting, physiography and regional geologic setting, geology of the proposed HST alternatives, near-surface soils along the proposed HST alternatives, geologic hazards, primary seismic hazards, secondary seismic hazards, areas of difficult excavation, and mineral and energy resources.

The affected environment for the three HST alternatives, which includes the north-south alignments, wyes, stations, and HMFs, is generally very similar within the Merced to Fresno Section. This similarity results from the geological processes that formed the surface and subsurface soils within the Central Valley of California. These geologic processes have led to a very flat topography, competent soils in most areas, and deep groundwater along most of the HST alternatives. These similar conditions also have led to similar sets of geologic hazards for the HST alternatives.

3.1 Study Area for Geology, Soils, and Seismicity

The potential area of disturbance associated with construction of the project includes the proposed HST alignments and associated facilities, as well as the roadway changes necessary to accommodate them.

Geologic hazards and seismic hazards, such as soil failures, settlement, corrosivity, shrink/swell, erosion, and earthquake-induced liquefaction risks, are direct effects that affect the area immediately adjacent to the HST alternatives, including the north-south alignments, wyes, stations, and HMFs. For assessment of these risks, the study area is 150 feet on either side of the project alternative footprints. The study area is a half-mile radius for subsurface gas hazards, mineral resources, and oil and gas resources. The study area expands to 2 miles around the proposed HMFs and the proposed stations. The regional study area encompasses the San Joaquin Valley for review of seismicity, faulting, and dam failure inundation. Earthquake faults were identified within a 62-mile distance from the proposed alignment.

The large regional study area is necessary to include the effects of some geologic hazards that could affect the project, such as ground shaking and seismically induced flooding, even though the occurrence is many miles from the site. Specifically, a large seismic event on the San Andreas fault, more than 60 miles away from the site, could cause ground shaking levels that result in seismic geologic hazards at the project vicinity, such as liquefaction. Similarly, failure of a dam 10 miles to the east of the project could result in inundation of the area, including the HST tracks, by flood waters from the dam failure.

3.2 Source of Information

Information for the discussion of the affected environment for geology, soils, and seismicity was collected from publicly available archives, databases, and published reports, including:

- City general plans from the cities of Atwater, Merced, Chowchilla, Madera, and Fresno for policies and geologic hazard mapping
- County general plans from Merced, Madera, and Fresno counties for policies and hazard mapping
- United States Geological Survey (USGS) for topographic maps, geologic maps, and geologic hazard mapping
- USGS and California Geological Survey (CGS) geologic maps, landslide maps, and seismic hazard maps
- Natural Resources Conservation Service (NRCS) for soils information
- California Division of Mines and Geology, Department of Conservation, and Division of Oil, Gas, and Geothermal Resources (DOGGR), and USGS reports and websites for mineral, fossil fuel, and geothermal resource mapping

- Area-specific Caltrans boring logs
- Area-specific geotechnical reports and environmental reports

The analysis included review of geotechnical data and conclusions included in two 15% design reports that were prepared for the project: *15% Geotechnical Report UPRR/SR99 Alternative* (Authority and FRA 2010a), and *15% Geotechnical Report BNSF Alternative Including Ave. 21 & Ave. 24* (Authority and FRA 2010b). These two reports summarize the geologic setting for the alignments, describe site conditions, and provide preliminary evaluations and recommendations for geologic hazards, natural chemical hazards and corrosion potential, and foundation support methods. These reports also summarize the results of geotechnical explorations conducted by Caltrans and others along or within the vicinity of the HST alignments. Much of the boring information had been obtained at stream and river crossings.

Site-specific geotechnical explorations have not been conducted to date for either 15% design or the EIR/EIS assessment of geology, soils, and seismicity. Interpretations and evaluations for 15% design and for the EIR/EIS assessment were based on existing information and interpretations of geology along the HST alignments.

3.3 Regulatory Setting

Key federal, state, and local jurisdictional laws and regulations that pertain to geology, soils, and seismicity and that are most relevant to the proposed project are summarized below. The summary of key federal, state, and local laws and regulations is followed by a listing of key design standards and guidelines that will be used during design and construction of the project. Use of these guides and standards help in mitigating the risks of hazards associated with geology, soils, and seismicity.

3.3.1 Federal

National Environmental Policy Act (NEPA) [42 United States Code Section 4321 et seq.]

NEPA requires the consideration of potential environmental effects, including potential effects to geology, soils, and geologic resources, in the evaluation of any proposed federal agency action. NEPA also obligates federal agencies to consider the environmental consequences and costs in their projects and programs as part of the planning process. General NEPA procedures are set forth in the Council on Environmental Quality regulations 23 CFR 771.

3.3.2 State

CEQA [Section 21000 et seq.] and CEQA Guidelines [Section 15000 et seq.]

CEQA requires state and local agencies to identify the significant environmental impacts of their actions, including potential significant impacts on geology, soils, and geologic resources, and to avoid or mitigate those impacts, when feasible.

Alquist-Priolo Earthquake Fault Zoning Act [California Code of Regulations Section 2621 et seq.]

This act provides policies and criteria to assist cities, counties, and state agencies in the exercise of their responsibility to prevent the location of developments and structures for human occupancy across the trace of active faults.

Seismic Hazards Mapping Act [Public Resources Code Sections 2690 to 2699.6]

The Seismic Hazards Mapping Act requires that site-specific geotechnical investigations be conducted within the zones of required investigation to identify and evaluate seismic hazards and formulate mitigation measures prior to permitting most developments designed for human occupancy.

Surface Mining and Reclamation Act [Public Resources Code, Division 2, Chapter 9, Section 2710 et seq.]

This act was enacted to address the need for a continuing supply of mineral resources and is intended to prevent or minimize the adverse impacts of surface mining on public health, property, and the environment.

California Building Standards Code [California Code of Regulations Title 24]

The California Building Standards Code governs the design and construction of buildings, associated facilities and equipment and applies to buildings in California.

By following the federal and state regulations listed above, the Merced to Fresno Section would meet the objectives and policies that deal with public health and safety and environmental protection associated with geology, soils, and seismic activities as addressed in these plans.

3.3.3 Regional and Local Regulatory Framework

The State of California requires all cities and counties to adopt plans that provide objectives and policies addressing public health and safety, including protection against the impacts of seismic ground motions, fault ruptures, and geological and soils hazards. The proposed project would be built in Merced, Madera, and Fresno counties, and within the cities of Merced, Le Grand, Chowchilla, Madera, and Fresno. These counties and cities have developed general plans that contain goals and policies to minimize negative impacts during construction and during use or operation of a project. These include goals and policies related to grading and erosion control, dust emission control, geologic hazards, and other policies related to geology, soils, seismicity, and mineral and energy resources.

Table 3-1 lists regional and local plans and policies that were identified and considered in the preparation of this analysis. These plans and policies have been enacted by the cities and counties along the proposed alignments and at the locations of proposed stations and HMFs and will serve as a basis for the design, construction, and operation of the HST project.

Table 3-1
 Local Plans and Policies

Policy Title	Summary
Merced County	
Merced County General Plan (Merced County 1990)	Provides goals, objectives, policies, and implementation to protect people and structures from known seismic and geologic hazards and to manage soil erosion, protect water quality, mineral, energy, historical, and air resources. <ul style="list-style-type: none"> • Chapter 5 Safety: <ul style="list-style-type: none"> - Goal 1, Objective 1.A addresses seismic and geologic hazards. - Goal 3, Objective 3.A, Policy 2, Policy 3, and Implementation of the Uniform Building Code related to construction on unstable soils address unstable soils, slope instability, subsidence, and liquefaction. • Chapter 6 Open Space/Conservation: Goal 2, Objective 2.A, Policies 1 and 3 address soil erosion.
City of Atwater	
City of Atwater General Plan (City of Atwater 2000), Chapter 5, Seismic and Public Safety	Provides goals, policies, and implementation programs for seismic activity, liquefaction, ground subsidence, and wind erosion. <ul style="list-style-type: none"> • Goal SF-1 and Policy SF-1.1 address seismic activity.

Policy Title	Summary
	<ul style="list-style-type: none"> • Goal SF-2 and Policy SF-2.1 address liquefaction. • Goal SF-3 and Policy SF-3.1 address ground subsidence. • Goal SF-7, Policy SF-7.1, and Implementation Program SF-7.a address soil erosion by wind.
City of Merced	
City of Merced General Plan (City of Merced 1997)	Provides goals and policies for conservation of soil, air quality, and safety from hazards of earthquake activity and other geologic activity. <ul style="list-style-type: none"> • Chapter 7 Open Space, Conservation, and Recreation: Goal OS-5, Policy OS-5.2, and Implementation Actions 5.2.a and 5.2.c address conservation of soil resources and soil erosion. • Chapter 8 Sustainable Development: Goal SD-1, Policy SD-1.6, and Implementation Action 1.6a address air quality and dust and particulate emissions during construction, grading, excavation, and demolition. • Chapter 11 Safety: <ul style="list-style-type: none"> - Goal S-2, Policy S-2.1, Implementation Action 2.1, and Policy S-2.2 address seismic safety. - Policy S-2.3 addresses ground failure and subsidence. - Policy S-3.2 addresses dam failure.
Madera County	
Madera County General Plan (Madera County 1995a), Part II	Provides goals, policies, and implementation programs to protect and enhance natural qualities of streams, creeks, and groundwater; to conserve mineral resources; and to minimize loss of life, injury, and property damage due to seismic and geologic hazards including landslide hazards, unstable slopes, steep slopes, and expansive soils. <ul style="list-style-type: none"> • Section 5 Agricultural and Natural Resources: <ul style="list-style-type: none"> - Goal 5.C, Policy 5.C.2, and Implementation Program 5.1 address water quality, sedimentation and erosion, diversion or obstruction of stream channels and pollution of waterways with detrimental material. - Goal 5.I and Policy 5.I.2 address mineral resources. • Section 6 Health and Safety: <ul style="list-style-type: none"> - Goal 6.A and Policy 6.A.1 address geologic and seismic hazards including ground shaking, landslides, liquefaction, and critically expansive soils. - Policies 6.A.2 and 6.A.3 address landslide hazards, unstable slopes, and steep slopes. - Implementation Program 6.1-Uniform Building Code addresses seismic concerns.
City of Chowchilla	
City of Chowchilla General Plan (City of Chowchilla 2009)	Provides objectives and policies to improve air quality and minimize risks posed by geologic or seismic activity. <ul style="list-style-type: none"> • Open Space and Conservation Element: Objective OS-22, Policy OS 22.3, and Implementation Measure OS 22.3.A address air quality and dust during construction/demolition, and particulate emissions from construction, grading, excavation, and demolition. • Public Safety Element: Objective PS 1 and Policies PS 1.1 to PS 1.4 address geologic or seismic instability including liquefaction and slumping.

Policy Title	Summary
City of Madera	
City of Madera General Plan (City of Madera 2009a)	Provides goals, policies, and action items for water quality, air quality, and seismic or geologic hazards. <ul style="list-style-type: none"> • Chapter 5 Conservation Element: <ul style="list-style-type: none"> - Goal CON-4, Policy CON-10, and Action Item CON-10.1 address water quality and site runoff control. - Goal CON-11, Policy CON-28, and Action Item CON-28 address air quality, dust, and particulate emissions from construction, grading, excavation, and demolition. • Chapter 6 Health and Safety Element: Goal HS-1 and Policy HS-8 address safe housing, and protection from damage caused by earthquakes, geologic conditions, and soil conditions.
Fresno County	
Fresno County General Plan (Fresno County 2000a)	Provides goals and policies to protect and enhance water quality, to conserve mineral deposits and oil and gas resources, to improve air quality, and to address seismic and geologic hazards including shrink-swell or expansive soils, soil erosion, unstable slopes, steep slopes, and landslide hazards. <ul style="list-style-type: none"> • Chapter 5, Open Space and Conservation Element: <ul style="list-style-type: none"> - Goal OS-A, and Policies OS-A.25 and OS-A.26 address water quality and sedimentation and soil erosion. - Goal OS-C and Policies OS-C.2, OS-C.9, and OS-C.10 address mineral deposits and oil and gas resources. - Goal OS-G, Policy OS-G.13, and Implementation Program OS-G.C address air quality and dust control. • Chapter 6, Health and Safety Element: <ul style="list-style-type: none"> - Goal HS-D addresses minimizing the loss of life, injury, and property damage due to seismic and geologic hazards. - Policies HS-D.2, HS-D.3, HS-D.4, and HS-D.7 address seismic and geologic hazards including earthquake fault zones and seismic zones. - Policy HS-D.8 addresses shrink-swell or expansive soils. - Policy HS-D.9 addresses soil erosion. - Policy HS-D.10, HS-D.11, and HS-D.12 address unstable slopes, steep slopes, and landslide hazards.
City of Fresno	
City of Fresno General Plan (City of Fresno 2002)	Provides objectives and policies regarding mineral resources and public health and safety, including seismic protection, geological and soils hazards, and bluff preservation protection. <ul style="list-style-type: none"> • Chapter 4.G Resource Conservation Element: Objective G-7 and Policy G-7-d address the conservation of aggregate mineral resources. • Chapter 4.I Safety Element: <ul style="list-style-type: none"> - Objective I-3, and Policies I-3-a, I-3-c, and I-3-d address geological unstable conditions that include seismic hazards, and geological and soils hazards. - Objective I-4 and Policy I-4-a address geologic hazards along the San Joaquin River bluffs.

3.3.4 Design Standards and Guidelines

The design and construction of the HST System would use federal and state design guidelines and standards. The intent of these guidelines and standards is to provide functional facilities that protect the public that either uses the facilities or is affected by the use of the facility. The system for the HST includes the rail track for at-grade, depressed, and elevation locations; the stations for unloading and loading passengers; and the maintenance facilities. Each component of the system would be designed to handle normal operating loads from the weight of the structure or train, as well as loads from environmental effects that range from seismic shaking to wind forces. At locations where geologic conditions present a hazard, the guidelines and standards provide minimum requirements for characterizing the geologic conditions and then addressing the design issue, such as the stability of slopes, the corrosion of materials, and BMPs for water and wind erosion, stream sedimentation, or dust control.

Some of the guidelines and standards that would be used as part of design, and that would mitigate impacts from geology, soils, and seismicity, include the following:

- **2010 AASHTO Load and Resistance Factor Design (LRFD) Bridge Design Specifications (5th Edition) and the 2009 AASHTO Guide Specifications for LRFD Seismic Bridge Design:** These documents provide guidance for characterization of soils, as well as methods to be used in the design of bridge foundations and structures, retained cuts and retained fills, at-grade segments, and buried structures. These design specifications would provide minimum specifications for evaluating the seismic response of the soil and structures.
- **Federal Highway Administration Circulars and Reference Manuals:** These documents provide detailed guidance on the characterization of geotechnical conditions at sites, methods for performing foundation design, and recommendations on foundation construction. These guidance documents include methods for designing retaining walls used for retained cuts and retained fills, foundations for elevated structures, and at-grade segments. Some of the documents include guidance on methods of mitigating geologic hazards that are encountered during design.
- **AREMA Manual (2009):** These guidelines deal with rail systems. Although these guidelines cover many of the same general topics as the AASHTO, they are more focused on best practices for rail systems. The manual includes principles, data, specifications, plans, and economics pertaining to the engineering, design, and construction of railways.
- **California Building Code (CBC):** CBC is based on 2009 IBC. This code contains general building design and construction requirements relating to fire and life safety, structural safety, and access compliance.
- **IBC and American Society of Civil Engineers (ASCE)-7:** These codes and standards provide minimum design loads for buildings and other structures. They would be used for the design of the maintenance facilities and stations. Sections in the IBC and ASCE-7 provide minimum requirements for geotechnical investigations, levels of earthquake ground shaking, minimum standards for structural design, and inspection and testing requirements.
- **Caltrans Design Standards:** Caltrans has specific minimum design and construction standards for all aspects of transportation system design, ranging from geotechnical explorations to construction practices. Caltrans design standards include state-specific amendments to the AASHTO LRFD Bridge Design Specifications and Guide Specifications for LRFD Seismic Bridge Design. These amendments provide specific guidance for the design of deep foundation used to support elevated structures, for design of mechanically stabilized earth (MSE) walls used for retained fills, and for design of various types of cantilever (e.g., soldier pile, secant pile, and tangent pile) and tie-back walls used for retained cuts.

- **American Society for Testing and Materials (ASTM) International:** ASTM International has developed standards and guidelines for all types of material testing, from soil classifications to pile load testing or compaction testing through to concrete strength testing. The ASTM standards also include minimum performance requirements for materials. Most of the guidelines and standards cited above use ASTM or a corresponding series of standards from AASHTO to assure that required/intended quality is achieved in the constructed project.

Applicable codes for the design of the HST facilities would be selected from the guidelines and standards identified above, depending on the specific component of the design. Where guidelines and standards cover the same components of design, the lead agency would select from the various guidelines and standards based on specific applicability to the project. Because of the types of facilities involved, all of these guidelines and standards would be used on some element of the project.

Relative to mitigating impacts from geology, soils, and seismicity, these guidelines and standards provide requirements for evaluating soil conditions, defining seismic loads, and evaluating the response of the foundation systems. Minimum performance requirements are also provided. The guidelines and standards also provide direction when minimum performance requirements are not met. By implementing these requirements, impacts caused by or resulting from geology, soils, and seismicity are appropriately identified, designed for, and mitigated through the standard design process.

Engineering geologists and geotechnical engineers who design the HST facilities are obligated to use these guidelines and standards. To meet professional licensing requirements, contract design documents would have to be signed and stamped by engineering geologists, civil engineers, and geotechnical engineers registered in California, certifying that the designs have been completed in a manner that meets minimum standards and is protective of the public.

3.4 Physiography and Regional Geologic Setting

The project is in the Central Valley of California, which is in the Great Valley Geomorphic and Physiographic Province (CGS 2002). The Central Valley is a large, flat valley bound by the Klamath and Trinity mountains to the north, the southern Cascade Range and Sierra Nevada to the east, the San Emigdio and Tehachapi mountains to the south, and the Coast Ranges and San Francisco Bay to the west. The Central Valley consists of the Sacramento Valley to the north and the San Joaquin Valley to the south. The Merced to Fresno Section is within the San Joaquin Valley, which is bound to the north by the Sacramento-San Joaquin Delta in Stockton.

3.4.1 Topography

The study area crosses the San Joaquin Valley. This valley is relatively flat-lying and consists of large alluvial fans sloping gently down to the west from the Sierra Nevada, and shorter, steeper fans sloping down to the east from the Coast Ranges. The San Joaquin River at the toe of these fans is offset to the western side of the Central Valley, and the river itself flows east-west through the HST alignments, and then northwest to the Sacramento-San Joaquin Delta.

Elevations across the proposed locations of the HST alternatives and HMFs range between +170 feet North American Vertical Datum of 1988 (NAVD 88) at the northern end to about +292 feet NAVD 88 at the southern end, with a high point of +305 feet NAVD 88 near Highway City. There is a general downward gradient in the study area to the west-southwest, determined principally by the gentle slope of the alluvial fans extending from the Sierra Nevada in the east to the center of the San Joaquin Valley to the west.

The closest mountains are about 10 miles east of the UPRR/SR 99 Alternative and 7 miles east of the BNSF Alternative. The only steep slopes (defined for this project as slopes taller than 15 feet and steeper than 2H:1V [horizontal to vertical], or 27 degrees) are along river and creek banks. There are numerous primary rivers, streams, or intermittent creeks that intersect the UPRR/SR 99, BNSF, and the Hybrid Alternatives within Merced, Madera, and Fresno counties. These waterways or drainages are listed and

illustrated in the *California HST Merced to Fresno Section Draft Project EIR/EIS Hydrology and Floodplains Technical Report* (Authority and FRA 2011). In three locations, the slope height is 15 feet or taller: Fresno River (15 feet slopes), Berenda Creek (15- to 20-foot slopes), and San Joaquin River (about 50 feet). Most slopes are less than 10 feet, with slope angles that range from relatively flat to occasional slopes steeper than 45 degrees.

3.4.2 Geologic History

The Central Valley occupies a trough created about 65 million years ago by tectonic forces related to the collision of the Pacific and North American plates. Fluctuations in sea level caused the valley to be flooded with ocean water for the next 60 million years. About 5 million years ago, the area became enclosed as a result of the uplift of the Coast Ranges and the deposition of sediment in the valley. About 2 million years ago, a series of glacial episodes caused much of the valley to become a freshwater lake. After the last glaciation, about 10,000 years ago, huge streams formed from glacial meltwater and rushed down the west slope of the Sierra Nevadas, turning large areas of the San Joaquin Valley into marshes and lakes. Most of these lakes have since receded (San Joaquin Geological Society 2009).

The San Joaquin Valley is a structural trough with an approximately 6-mile-thick layer of continental and marine sediments overlying rock (Kleinfelder 2004). Continental sediments were deposited during erosion of the surrounding mountains, and marine sediments were deposited during periodic inundation by the Pacific Ocean. Continental sediments are located above the marine sediments and are the geologic units at the surface in the study area. Continental sediments consist of alluvium, lake, and floodplain deposits comprising clay, silt, sand, gravel, and cobbles. These sediments are generally finer-grained near the center of the valley and coarser-grained along the flanks of the valley (Authority and FRA 2008). More than half the thickness of the continental sediments is composed of fine-grained (clay, sandy clay, sandy silt, and silt) stream and lake deposits (Galloway and Riley 1999).

3.5 Geology along Proposed HST Alternatives

The geology of the areas of the proposed HST alternatives, including the north-south alignments, wyes, stations, and HMFs, is variable within the project limits, despite the relative flat topography. This variability is the result of various depositional processes that resulted in the thick accumulation of marine and continental sediments. The following sections summarize the surficial geology, subsurface geotechnical conditions, and groundwater characteristics for the HST alternatives.

3.5.1 Surficial Geology

Geologic formations along the proposed alignments include the Post-Modesto, Modesto, Riverbank, Turlock Lake, North Merced Gravel, Laguna, Mehrten, Great Valley Sequence, and Pleistocene nonmarine formations. The Modesto, Riverbank, and Turlock Lake formations are similar to one another in four respects: (1) the parent material of the sand and silt fraction, (2) a tendency toward coarser material at the top of each geologic layer, (3) deposition as sequential overlapping alluvial terrace and fan systems, and (4) the origins of much of the sediment. Bedrock is encountered about 6 miles below ground surface (bgs) along the HST alternatives.

Surficial geology underlying the study area consists primarily of alluvial deposits of clay, silt, sand, and gravel with varying grain sizes and content. The soil type and consistency of these deposits vary from location to location, and even within each unit.

Figures 3-1 through 3-4 identify the distribution of surficial geology in the Merced, Chowchilla, Madera, and Fresno project vicinities, respectively, along each alternative and at the HMF sites. These maps were developed from geologic maps prepared by Marchand and Allwardt (1978)¹ and Matthews and Burnett (1965). Descriptions of the surficial geology shown in Figures 3-1 through 3-4 are provided in Table 3-2,

¹ The 1978 map by Marchand and Allwardt was used instead of the geology map in Marchand and Allwardt (1981) because the geology is more detailed in the 1978 map.

based on commentary provided on the maps by Marchand and Allwardt (1978) and Matthews and Burnett (1965). Table 3-3 identifies the predominant geology from north to south within each of the alternatives. Tables 3-4 and 3-5 list mapped surficial geology underlying each alternative.

3.5.1.1 Surficial Geology along HST Alternatives

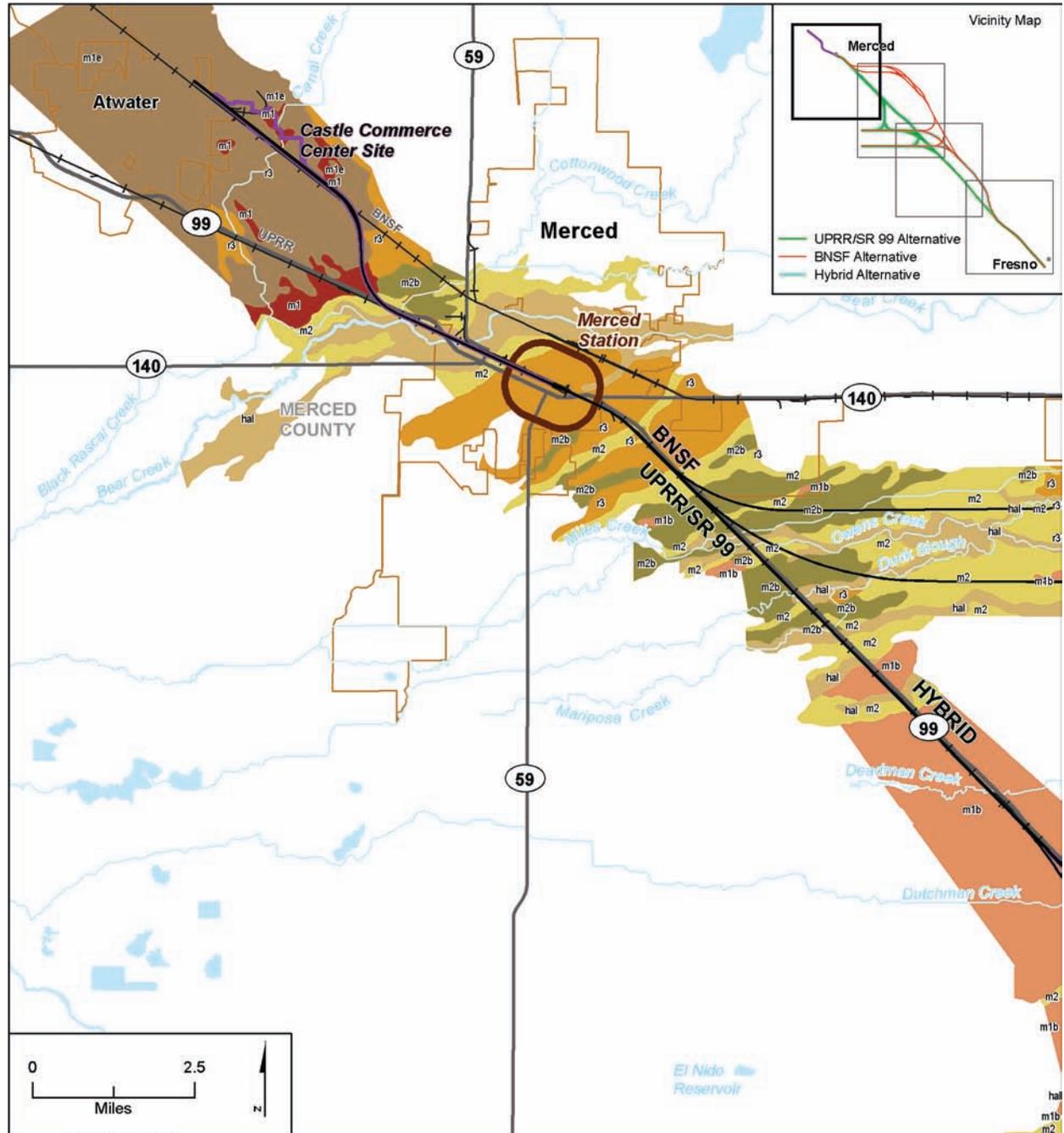
Predominant surficial geology encountered along the north/south alignments of the alternatives are the Modesto Formation (MF) upper member (m2), the Riverbank Formation (RF) middle unit (r2), the Turlock Lake Formation (t2), and the Great Valley Sequence – fan deposits (Qf) (Figures 3-1 through 3-4).

- The MF upper member (m2) is coarse alluvium consisting of sand, silt, and gravel.
- The RF middle unit (r2) is alluvium consisting of sand, silt, and gravel.
- The Turlock Lake Formation (t2) is alluvial sand and minor amount of gravel overlying stratified fine sand, silt, and minor clay.
- The Great Valley Sequence consists of fan deposits (Qf), but no description was provided by Marchand and Allwardt (1978) and Matthews and Burnett (1965).

Predominant surficial geology present at the proposed station sites are the RF upper unit (r3) at the Downtown Merced Station and Great Valley Sequence – fan deposits (Qf) at the Downtown Fresno Station. The RF upper unit (r3) is alluvium consisting of sand, silt, and gravel. There is no description available for the Great Valley Sequence – fan deposits.

Predominant surficial geology encountered along the Ave 24 Wye and the West Chowchilla design option alignment of the UPRR/SR 99 Alternative are the MF upper member (m2) and MF lower member (m1b). The MF upper unit (m2) is described above and the MF lower member (m1b) is fine alluvium consisting of sand, silt, and clay of interdistributary areas, lower fans, and flood basins. Predominant surficial geology encountered along the Ave 24 Wye alignment of the BNSF Alternative are the MF upper member (m2) and the RF middle unit (r2), as described above.

Predominant surficial geology encountered along the Ave 21 Wye alignments of the UPRR/SR 99 Alternative are the MF upper member (m2) and the RF upper unit (r3), and the units along the BNSF Alternative are the MF upper member (m2), RF upper unit (r3), and RF middle unit (r2), as described above.



Source: USGS (1965, 1978).

- HST Alignment
- Potential Heavy Maintenance Facility
- Station Study Area
- City Limit
- - - County Boundary
- + + + Railroad
- ■ ■ Southern Limit of Coverage of Marchand and Allwardt (1978)
- ■ ■ Northern Limit of Coverage of Matthews and Burnett (1965)

Coverage of Marchand and Allwardt (1978)
 Youngest to Oldest

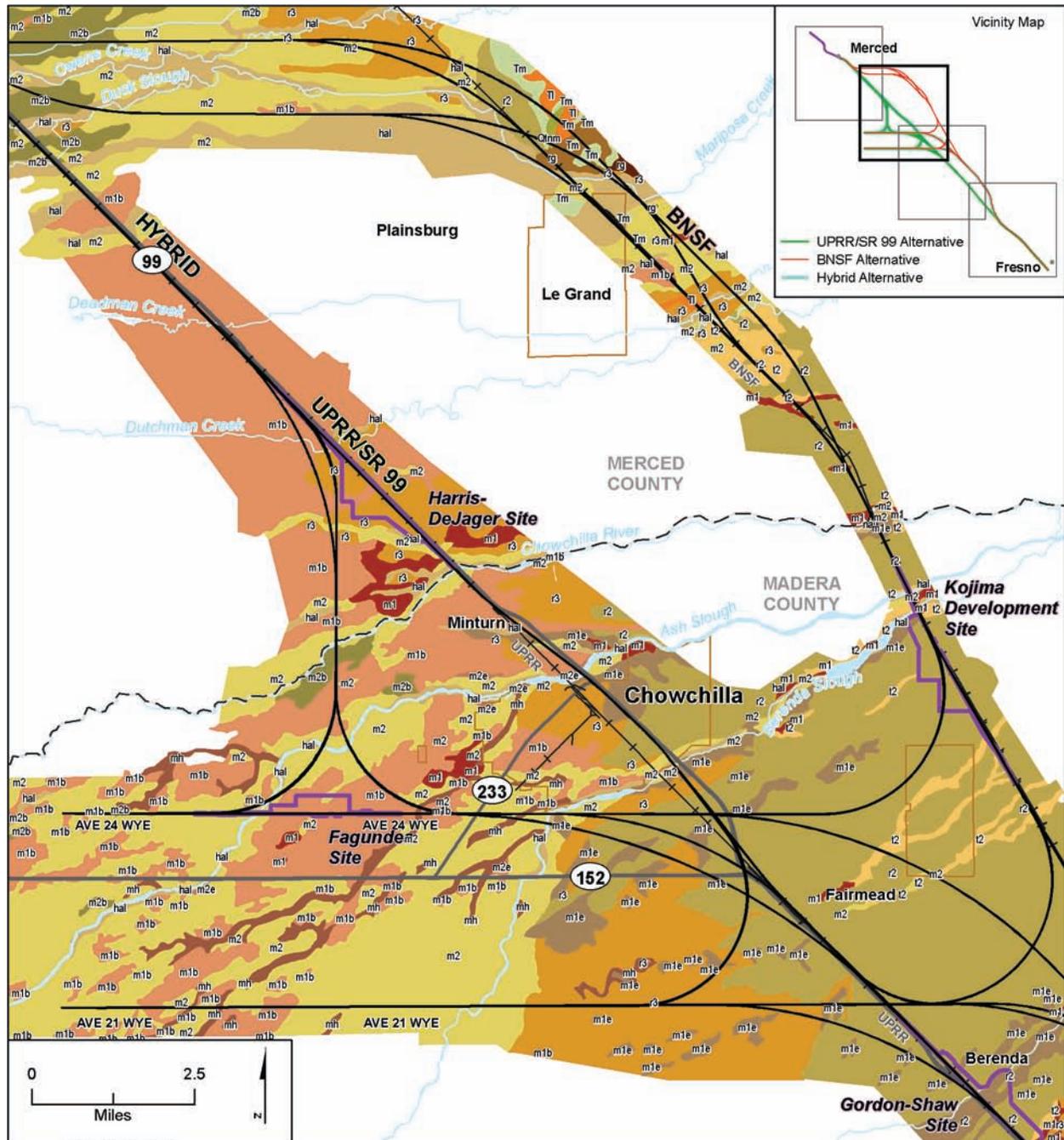
- hal, Post-Modesto
- mh, Undifferentiated post-Modesto and Modesto Formation
- m2, Modesto Formation - Upper member
- m2b, Modesto Formation - Upper member
- m2e, Modesto Formation - Upper member
- m1, Modesto Formation - Lower member
- m1b, Modesto Formation - Lower member
- m1e, Modesto Formation - Lower member
- r3, Riverbank Formation, upper unit
- rg, North Merced Riverbank

MF_EIS_GS_13-16_a

Jun 29, 2011

- rg, Riverbank Formation, upper unit
 - r2, Riverbank Formation, middle unit
 - t2, Turlock Lake Formation
 - Qtm, North Merced Gravel
 - Tl, Laguna Formation
 - Tm, Mehrten Formation
- Coverage of Matthews and Burnett (1965)**
- Qsc, Great Valley Sequence - Stream Deposits
 - Qf, Great Valley Sequence - Fans
 - Qc, Pleistocene nonmarine

Figure 3-1
 Surficial Geology within the Merced Project Vicinity



Source: USGS (1965, 1978).

- HST Alignment
- Potential Heavy Maintenance Facility
- Station Study Area
- City Limit
- - - County Boundary
- + + + Railroad
- Southern Limit of Coverage of Marchand and Allwardt (1978)
- Northern Limit of Coverage of Matthews and Burnett (1965)

Coverage of Marchand and Allwardt (1978)
 Youngest to Oldest

- hal, Post-Modesto
- mh, Undifferentiated post-Modesto and Modesto Formation
- m2, Modesto Formation - Upper member
- m2b, Modesto Formation - Upper member
- m2e, Modesto Formation - Upper member
- m1, Modesto Formation - Lower member
- m1b, Modesto Formation - Lower member
- m1e, Modesto Formation - Lower member
- r3, Riverbank Formation, upper unit
- rg, North Merced Riverbank

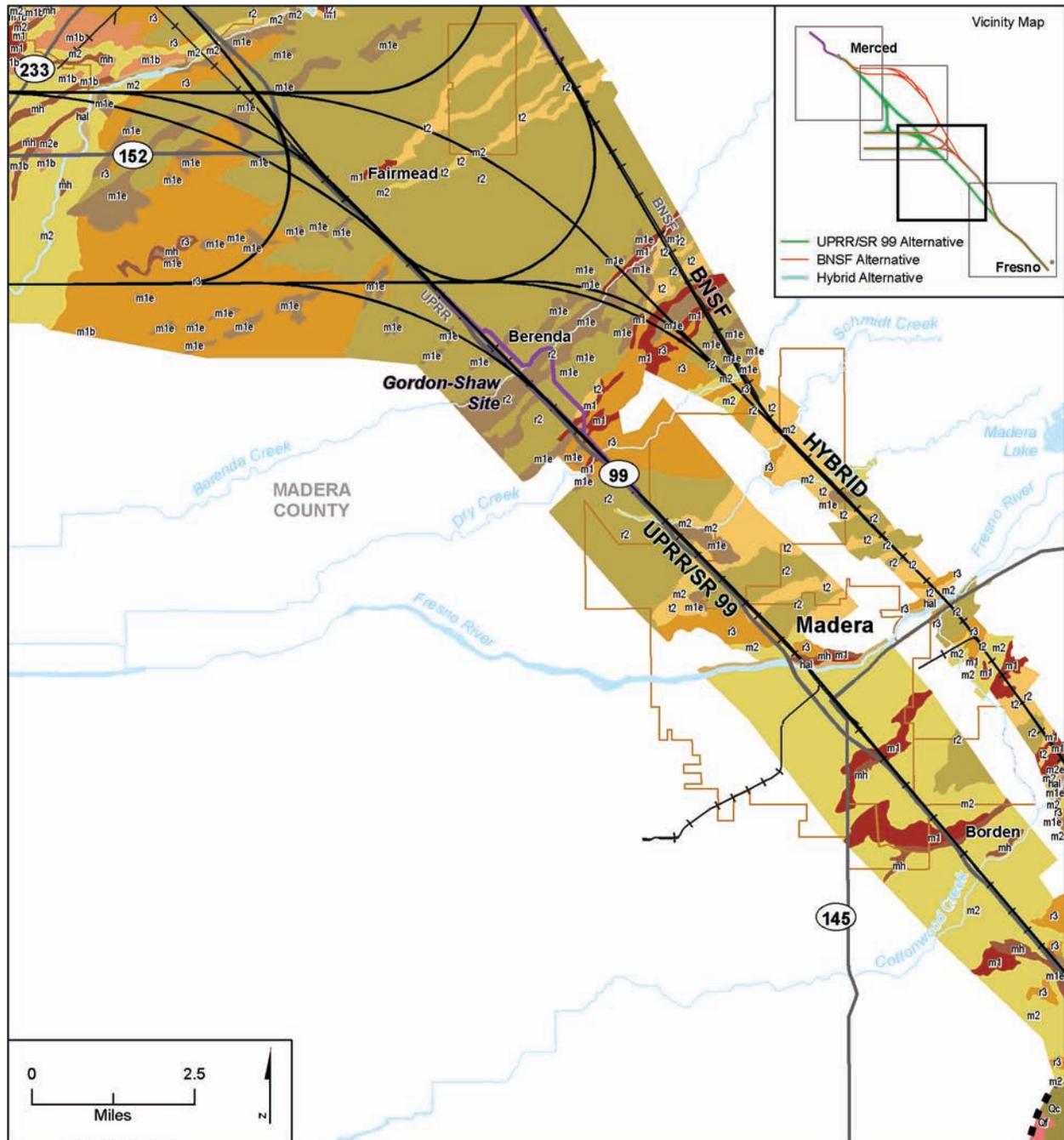
- rg, Riverbank Formation, upper unit
- r2, Riverbank Formation, middle unit
- t2, Turlock Lake Formation
- Qtnm, North Merced Gravel
- Tl, Laguna Formation
- Tm, Mehrten Formation

Coverage of Matthews and Burnett (1965)

- Qsc, Great Valley Sequence - Stream Deposits
- Qf, Great Valley Sequence - Fans
- Qc, Pleistocene nonmarine

MF_EIS_GS_13-16_b Jun 29, 2011

Figure 3-2
 Surficial Geology within the Chowchilla Project Vicinity



Source: USGS (1965, 1978).

- HST Alignment
- Potential Heavy Maintenance Facility
- Station Study Area
- City Limit
- - - County Boundary
- + + Railroad
- ■ Southern Limit of Coverage of Marchand and Allwardt (1978)
- ■ Northern Limit of Coverage of Matthews and Burnett (1965)

Coverage of Marchand and Allwardt (1978)

Youngest to Oldest

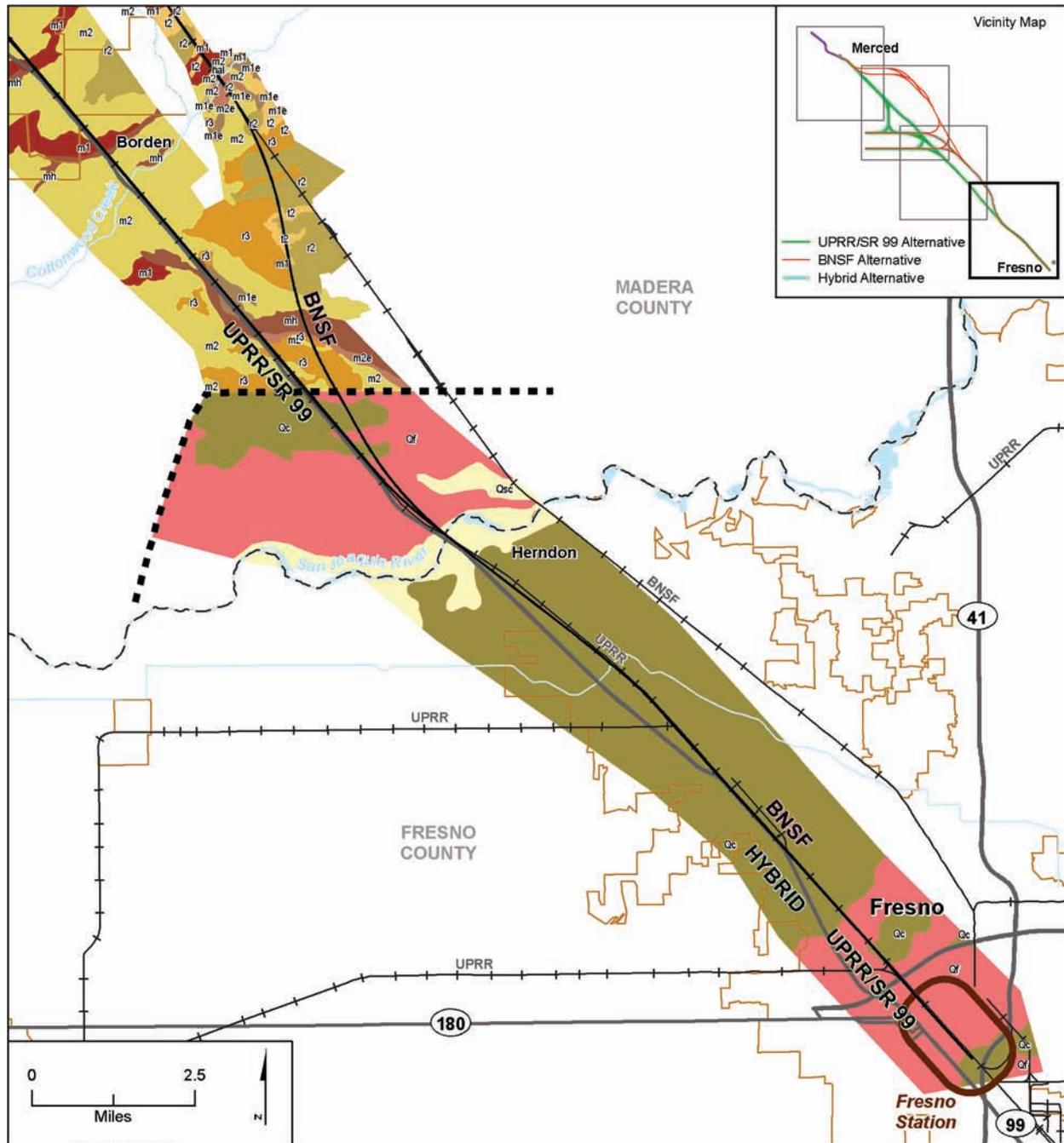
- hal, Post-Modesto
- mh, Undifferentiated post-Modesto and Modesto Formation
- m2, Modesto Formation - Upper member
- m2b, Modesto Formation - Upper member
- m2e, Modesto Formation - Upper member
- m1, Modesto Formation - Lower member
- m1b, Modesto Formation - Lower member
- m1e, Modesto Formation - Lower member
- r3, Riverbank Formation, upper unit
- rg, North Merced Riverbank

MF_EIS_GS_13-16_c

Jun 29, 2011

- rg, Riverbank Formation, upper unit
 - r2, Riverbank Formation, middle unit
 - t2, Turlock Lake Formation
 - Qtnm, North Merced Gravel
 - T1, Laguna Formation
 - Tm, Mehrten Formation
- Coverage of Matthews and Burnett (1965)**
- Qsc, Great Valley Sequence - Stream Deposits
 - Qf, Great Valley Sequence - Fans
 - Qc, Pleistocene nonmarine

Figure 3-3
 Surficial Geology within the Madera Project Vicinity



Source: USGS (1965, 1978).

MF_EIS_GS_13-16_d Jun 29, 2011

- HST Alignment
 - Potential Heavy Maintenance Facility
 - Station Study Area
 - City Limit
 - - - County Boundary
 - + + + Railroad
 - Southern Limit of Coverage of Marchand and Allwardt (1978)
 - Northern Limit of Coverage of Matthews and Burnett (1965)
- Coverage of Marchand and Allwardt (1978)**
 Youngest to Oldest
- hal, Post-Modesto
 - mh, Undifferentiated post-Modesto and Modesto Formation
 - m2, Modesto Formation - Upper member
 - m2b, Modesto Formation - Upper member
 - m2e, Modesto Formation - Upper member
 - m1, Modesto Formation - Lower member
 - m1b, Modesto Formation - Lower member
 - m1e, Modesto Formation - Lower member
 - r3, Riverbank Formation, upper unit
 - rg, North Merced Riverbank
- Coverage of Matthews and Burnett (1965)**
- rg, Riverbank Formation, upper unit
 - r2, Riverbank Formation, middle unit
 - t2, Turlock Lake Formation
 - Qtnm, North Merced Gravel
 - Tl, Laguna Formation
 - Tm, Mehrten Formation
 - Qsc, Great Valley Sequence - Stream Deposits
 - Qf, Great Valley Sequence - Fans
 - Qc, Pleistocene nonmarine

Figure 3-4
 Surficial Geology within the Fresno Project Vicinity

Table 3-2
 Summary of Mapped Surficial Geology

Map Symbol	Geologic Formation and Formation Subunit	Geologic Unit Type	Description
hal	Post-Modesto	Alluvium	alluvial sand, silt, and gravel associated with floodplains and low terraces
mh	Undifferentiated post-Modesto and Modesto Formation	Alluvium	alluvial sand, silt, and gravel; includes some young colluvium in foothill valley bottoms
m2	Modesto Formation - Upper member	coarse alluvium	alluvial sand, silt, and gravel of channels, terraces, and upper fans
m2b	Modesto Formation - Upper member	fine alluvium	alluvial sand, silt, and clay of interdistributary areas, lower fans, and flood basins, commonly stratified
m2e	Modesto Formation - Upper member	eolian sand	associated with subdued, stabilized dunes
m1	Modesto Formation - Lower member	coarse alluvium	alluvial sand, silt, and gravel of channels, terraces, and upper fans
m1b	Modesto Formation - Lower member	fine alluvium	alluvial sand, silt, and clay of interdistributary areas, lower fans, and flood basins, commonly stratified
m1e	Modesto Formation - Lower member	eolian sand	moderately well sorted sand
r3	Riverbank Formation ^a , upper unit	Alluvium	alluvial sand, silt, and gravel
Rg	Riverbank Formation, upper unit	lag gravel	gravel derived from regrading of North Merced and older gravels
r2	Riverbank Formation, middle unit	Alluvium	alluvial sand, silt, and gravel
t2	Turlock Lake Formation	arkosic alluvium	alluvial granitic sand and minor gravel overlying stratified fine sand, silt, and minor clay
Qtnm	North Merced Gravel	lag gravel	thin, locally derived pediment veneer of cobble gravel capping Tertiary and pre-Tertiary rocks
Tl	Laguna Formation	arkosic alluvium	granitic sand, silt, and minor gravel underlying the China Hat Gravel Member
Tm	Mehrten Formation	fluvial deposits	andesitic fluvial sand, silt, and minor gravel, presumably reworked from volcanic mudflow deposits to the northeast
Qsc	Great Valley Sequence – Stream Deposits	alluvial deposits	No description available
Qf	Great Valley Sequence – Fan Deposits	fan deposits	No description available
Qc	Pleistocene Nonmarine	alluvial deposits	No description available

^a Identification as Riverbank Formation is based upon available data but is a somewhat uncertain conclusion and subject to confirmation.
 Sources: Marchand and Allwardt (1978) and Matthews and Burnett (1965).

Table 3-3 summarizes the predominant surficial geology from north to south within each of the three HST alternatives, including the Ave 24 and 21 Wyes. Table 3-4 identifies the surficial geology underlying each alternative.

Table 3-3
 Predominant Surficial Geology

Location	UPRR/SR 99 Alternative	BNSF Alternative	Hybrid Alternative
Merced Area	Riverbank Formation – upper unit (r3): sand, silt, and gravel	Riverbank Formation – upper unit (r3): sand, silt, and gravel	Riverbank Formation – upper unit (r3): sand, silt, and gravel
Merced to Chowchilla Area	Modesto Formation – upper member (m2): sand, silt, and gravel; upper member (m2b) and lower member (m1b): sand, silt, and clay	Modesto Formation – upper member (m2): sand, silt, and gravel; upper member (m2b) and lower member (m1b): sand, silt, and clay Riverbank Formation – upper unit (r3) and middle unit (r2): sand, silt, and gravel	Modesto Formation – upper member (m2): sand, silt, and gravel; upper member (m2b) and lower member (m1b): sand, silt, and clay
Chowchilla Area	Riverbank Formation – middle unit (r2): sand, silt, and gravel	Riverbank Formation – middle unit (r2): sand, silt, and gravel	Riverbank Formation – middle unit (r2): sand, silt, and gravel
Ave 24 and 21 Wye Area	Modesto Formation – upper member (m2): sand, silt, and gravel Riverbank Formation – middle unit (r2): sand, silt, and gravel	Riverbank Formation – middle unit (r2): sand, silt, and gravel	Modesto Formation – lower member (m1b): sand, silt, and clay; and upper member (m2): sand, silt, and gravel Riverbank Formation – upper unit (r3): sand, silt, and gravel
Chowchilla to Madera Area	Riverbank Formation – middle unit (r2): sand, silt, and gravel	Riverbank Formation – middle unit (r2): sand, silt, and gravel Turlock Lake Formation – (t2): sand and minor gravel overlying fine sand, silt, and minor clay	Riverbank Formation – middle unit (r2): sand, silt, and gravel Turlock Lake Formation (t2): sand and minor gravel overlying fine sand, silt, and minor clay
Madera to Fresno County Line Area	Modesto Formation – upper member (m2): sand, silt, and gravel	Modesto Formation – upper member (m2): sand, silt, and gravel Riverbank Formation – middle unit (r2): sand, silt, and gravel	Modesto Formation – upper member (m2): sand, silt, and gravel Riverbank Formation – middle unit (r2) sand, silt, and gravel
County Line to Fresno Area	Pleistocene nonmarine (Qc): no description available	Pleistocene nonmarine (Qc): no description available]	Pleistocene nonmarine (Qc): no description available
Fresno Area	Pleistocene nonmarine (Qc): no description available	Pleistocene nonmarine (Qc): no description available	Pleistocene nonmarine (Qc): no description available

Table 3-4
 Surficial Geology by Alternative

Map Symbol	UPRR/SR 99 Alternative					BNSF Alternative			Hybrid Alternative		
	North-South Alignment	Downtown Merced Station	Downtown Fresno Station	Ave 24 Wye	Ave 21 Wye	North-South Alignment	Ave 24 Wye	Ave 21 Wye	North-South Alignments	Downtown Merced Station	Downtown Fresno Station
hal	✓	✓		✓		✓	✓		✓	✓	✓
mh	✓			✓	✓	✓	✓	✓	✓		✓
m2	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
m2b	✓			✓		✓	✓		✓		✓
m2e	✓					✓					
m1	✓					✓	✓	✓	✓		
m1b	✓			✓	✓	✓	✓	✓	✓		
m1e	✓			✓	✓	✓	✓	✓	✓		
r3	✓	✓		✓	✓	✓	✓	✓	✓		
rg						✓					
r2	✓			✓	✓	✓	✓	✓	✓		
t2	✓					✓	✓	✓	✓		
Qtnm						✓					
Tl						✓					
Tm						✓					
Qsc	✓					✓			✓		
Qf	✓		✓			✓			✓		✓
Qc	✓		✓			✓			✓		✓

3.5.1.2 HMF Alternative Sites

Predominant surficial geology encountered at the proposed HMF sites consists of MF lower member (m1e) at the Castle Commerce Center site, RF upper unit (r3) at the Harris-DeJager site, MF lower member (m1b) at the Fagundes site, and RF middle unit (r2) at the Gordon-Shaw and Kojima Development HMF sites. The RF upper unit (r3), RF middle unit (r2), and MF lower member (m1b) units are described above. The MF lower member (m1e) is eolian sand, consisting of moderately well-sorted sand. Table 3-5 identifies the surficial geology corresponding to the relevant HMF.

Table 3-5
 Surficial Geology for HMF Sites

Map Symbol	Castle Commerce Center	Harris-DeJager	Fagundes	Gordon-Shaw	Kojima Development
hal		✓	✓		✓
mh					
m2		✓	✓		✓
m1	✓	✓		✓	✓
m1b		✓	✓		
m1e	✓			✓	✓
r3		✓		✓	
r2				✓	✓
t2				✓	✓

3.5.2 Subsurface Geotechnical Conditions

This section summarizes generalized subsurface soil and groundwater conditions for the HST alternatives, including the north-south alignments, wyes, stations, and HMFs. The summary is based on a review of readily available geotechnical boring logs and groundwater contour maps. The intent of the review was to identify general subsurface soil and groundwater conditions that could, if not addressed, result in difficult construction, lead to poor long-term performance, or represent a hazard for future HST operations. This information forms part of the basis for the assessment of possible impacts that could occur during construction and operation of the HST System. Although this information is representative, it is by no means sufficient for design of the HST System. A much more detailed subsurface assessment and project-specific geotechnical evaluations will be conducted for the project once the preferred alternative and HMF site are selected, as part of the design phase.

3.5.2.1 Subsurface Soils

Representative boring logs were collected within and adjacent to the HST alternatives, including the north-south alignments, wyes, stations, and HMFs. Most of this information originated from geotechnical explorations conducted by Caltrans for the design of existing bridges that cross roadways, rail tracks, or rivers and streams along the north-south alignments or HMFs. Additional information originated from investigations for environmental cleanups or monitoring recorded in the State of California Water Resources Control Board GeoTracker database and also originated from explorations for assorted building projects along the alignments. The summaries of subsurface soil conditions for each HST alternative below are based on information from representative boring logs and summaries of subsurface information in Authority and FRA (2010a, 2010b), which are based on the information from the above sources. The information on boring logs typically includes engineering classification of soil samples, index and engineering properties, and field test results such as Standard Penetration Test blowcounts.

In general, geotechnical explorations for these locations indicate that soils generally consist of layers of clay, silt, and sand of varying grain-size distributions, consistencies, and thicknesses. Most soils along the alignments and at the HMFs are competent stiff silts and clays or dense sands. However, there are some occurrences of fine-grained soil that range from soft to stiff in consistency and cohesionless soils that can range from loose to very dense. Generally, less competent silts and sands are located in the upper 10 to 20 feet. Between 20 and 30 feet, soils are typically more competent, stiff or medium dense, silts and sands. Dense sands and hard silts are usually encountered at depths of 30 to 60 feet bgs.

UPRR/SR 99 Alternative

Subsurface soils along the UPRR/SR 99 Alternative generally comprise deposits of alluvial sediment characterized by layers of competent silty sand, clayey sand, and sandy silt, underlain by poorly graded sand and sandy silt. Thicknesses and depths of the soils vary throughout the study area. Localized deposits of soft or loose soils are possible, particularly near rivers and streams; however, their occurrence is much less frequent than the competent soils.

The stiff silts and clays and dense sands resist settlement under new imposed loads, and they exhibit good bearing capacity characteristics (e.g. high shear strength and low settlement potential) for structures that will be located on the soils, making them suitable for support of the HST track, retained fills, elevated guideways, stations, and HMFs. Where soft or loose soils occur, various methods are available during design and construction to address the impacts of these conditions, which are typically localized.

The following summary identifies soil conditions encountered at major bridges, going from the north end to the south end of the alignment:

- **Franklin Road Overcrossing:** At this location, soils consist of loose to medium dense silty sand in the upper 5 feet, underlain by dense to very dense sand and silty sand and hard to very hard silt and sandy silt to the bottom of the boring at 45 feet bgs.
- **Bear Creek:** The upper 10 to 20 feet of soil at Bear Creek comprises soft to stiff clayey silt or very loose clayey fine sand. This upper unit is underlain by 15 feet of medium dense fine sand with varying silt and clay content. At about 30 feet bgs, hard/dense clayey silt and clay are encountered to about 55 feet bgs, where fine-grained, silty sand is encountered to the bottom of the boring at 60 feet bgs.
- **East Merced Overhead:** The eastern side generally consists of a very hard silt layer to a depth of about 8 feet bgs, underlain predominantly by very stiff silts and medium dense sands to a depth of 40 feet. This layer is underlain by hard sandy silts and sandy clays to the bottoms of the borings at 65 feet bgs. The western side consists of medium dense to dense silty sands, underlain by very hard sandy clay and concretionary silt to a depth of about 32 feet bgs. Below 32 feet bgs, layers of medium dense sands and stiff to hard silts and clays are encountered to a depth of 75 feet bgs, where very stiff to hard silts and very dense sands occur to the bottoms of the borings at 90 feet bgs.
- **Miles Creek:** Soils at Miles Creek consist of 15 feet of stiff clay, underlain by stiff to very stiff silt with varying sand content to about 35 feet bgs. This upper unit is underlain by about 20 feet of interbedded stiff clay and medium dense sand; this unit is underlain by 20 feet of stiff to very stiff clay. Medium dense sand with varying silt and clay content is encountered at about 75 feet bgs, becoming dense at about 90 feet bgs to the bottom of the boring at 100 feet bgs.
- **Duck Slough Bridge:** Soils at Duck Slough Bridge are predominantly silts, including clayey silts and sandy silts, with occasional layers of sand and silty clay. On the eastern side, a layer of very hard silt is encountered at about 15 feet bgs. The silt is underlain by medium dense to dense silt to depths ranging from 50 to 60 feet. Dense to very dense silty sands are encountered below 50 to 60 feet bgs. On the western side, soils are loose/firm to dense/hard to the bottoms of the borings at 70 feet bgs. A 4-foot-thick layer of very hard silt is encountered at about 35 feet bgs.
- **Deadman Creek:** At Deadman Creek, soils consist of medium dense silt with varying sand content and sand with varying silt content to 45 feet bgs, becoming dense to very dense sand with varying silt and gravel content to 55 feet bgs. This upper unit is underlain by very stiff clay to the bottom of the boring at 70 feet bgs.
- **Dutchman Creek Bridge:** The western side of Dutchman Creek consists of medium dense sandy soils to a depth of about 17 feet. These soils are underlain by dense to very dense silty sand to about

32 feet bgs. Below 32 feet bgs, layers of medium dense sands and very stiff silts are encountered to the bottom of the boring at 65 feet bgs, except for a 5-foot-thick layer of very hard clayey silt at 40 feet bgs. On the eastern side, soils generally consist of very stiff silt to about 10 feet bgs, underlain by dense to very dense sands and hard silts to about 33 feet bgs. Very stiff silts and sandy silts are encountered below 33 feet bgs to the bottom of the boring at 60 feet bgs.

- **Chowchilla River:** The northern side of Chowchilla River generally consists of layered loose and medium dense silt and sand with varying silt content to about 40 feet, becoming layered medium dense and dense silty sand and silt to the bottoms of the borings up to 75 feet bgs. The southern side generally consists of layered medium dense silt, silty sand, and sand to about 45 feet bgs, becoming dense to very dense sand and silt with varying sand content to the bottoms of the borings at 60 feet bgs.
- **California Overhead:** Soils generally consist of medium dense sandy silt in the upper 10 feet, underlain by very dense silty sand with little gravel up to a depth of 30 feet. The silty sand layer is underlain by dense to very dense sand/silty sand and hard silt to the bottoms of the borings at 50 feet bgs.
- **Berenda Creek:** Subsurface soils at Berenda Creek generally consist of stiff to very stiff silt with some medium dense to dense sand layers and few gravel pockets up to 45 feet bgs. The silt and sand layers are underlain by dense to very dense sand to the bottoms of the borings at 80 feet bgs.
- **Dry Creek:** At Dry Creek, loose silt and firm clay occur in the upper 20 feet. These soils are underlain by very dense silt with varying sand content and sand with varying silt content to the bottom of the boring at 40 feet bgs.
- **Fresno River:** The banks of the Fresno River consist of about 40 to 45 feet of medium dense sand with varying amounts of gravel, underlain by dense to very dense sand to the bottoms of the borings at 60 and 65 feet. Along the river bottom, there is about 10 to 15 feet of medium dense, interbedded clay, silt, and sand. These soils are underlain by medium dense sand with varying silt content to 15 to 20 feet bgs. This is underlain by dense sand, with scattered layers of medium dense sand with varying silt content to 40 to 45 feet bgs, where the soils become very dense to the bottoms of the borings at 55 and 60 feet bgs.
- **West Fourth Street Overcrossing:** Soils at the West Fourth Street Overcrossing generally consist of medium dense sand with intermediate very stiff silt layers to the bottoms of the borings at 70 feet bgs.
- **Avenue 11 Overcrossing:** In general, medium dense to dense sand with few pockets of loose silty sand is encountered to a depth of about 30 feet at the Avenue 11 Overcrossing. The sand is underlain by dense to very dense sandy silt layers to the bottoms of the borings at 80 feet bgs.
- **Avenue 8 Overcrossing:** Soils at the Avenue 8 Overcrossing consist of medium dense sand with occasional silty sand layer up to 30 feet bgs, underlain by very dense sand to the bottoms of the borings at about 45 feet bgs.
- **San Joaquin River:** The northern riverbank generally consists of medium dense to dense layers of silt and sand to about 45 feet bgs, underlain by about 10 feet of hard sandy clay. The sandy clay is underlain by medium dense to dense silty sand to the bottom of the boring at about 75 feet bgs. Soils near the river bottom generally consist of medium dense to very dense layers of sand and gravel with varying amounts of silt content and some layers of very dense silt and hard clay to the bottoms of the borings up to 100 feet bgs. Near the southern riverbank, there is about a 10-foot layer of loose, interbedded sand and silt encountered at about 15 feet bgs.
- **Grantland Avenue Undercrossing:** Subsurface soils at the Grantland Avenue Undercrossing generally consist of very loose sand with gravel in the upper 10 feet, underlain by dense sand/silty sand with few interbedded hard sandy silt lenses to the bottom of the boring at 45 feet bgs.

- **Shaw Avenue Overcrossing:** At the Shaw Avenue Overcrossing, soils consist of medium dense to dense sand with interbedded very stiff silt pockets in the upper 54 feet, underlain by dense silty sand to the bottoms of the borings at 60 feet bgs.
- **Clinton Avenue Overcrossing:** Subsurface soils at the Clinton Avenue Overcrossing generally consist of medium dense to dense sand in the upper 15 to 30 feet, underlain by dense to very dense sand/silty sand to the bottoms of the borings at 70 feet bgs.

BNSF Alternative

Results of the limited exploration information indicate that soils along the BNSF Alternative are predominately alluvial soils and are generally similar. These alluvial soils consist of layers of silty sand, clayey sand, and sandy silt, underlain by poorly graded sand and sandy silt. In view of the general proximity of the BNSF alternative to the UPRR/SR 99 alternative, as well as the similarity in mechanisms forming the soil profiles along the two alternatives, characteristics of the soils along the two alignments are generally expected to be similar. The following summary identifies soil conditions encountered along the BNSF Alternative from the north end to the south end of the alternative:

- **BNSF Railroad Underpass at G Street:** In this area soils consist of loose sand and soft lean clay in the upper 10 feet, underlain by interbedded layers of stiff to hard silt and clay and medium to very dense sand extending down to about 100-foot deep.
- **Bridge BR No. 39-0142/RL, Merced:** On the west side, soils consist of hard to very hard silt in the upper 10 feet, underlain by medium dense to very dense sand and sandy/clayey silt to a depth of approximately 30 feet. These soils were underlain by very hard silt to a depth of about 35 feet, which was underlain by very stiff to hard silts and clays to 50 feet. On the east side, hard to very hard silt was encountered in the upper 10 feet, underlain by very stiff to hard silts and sandy silt to a depth of about 35 feet, underlain by hard clayey silt to a depth of about 40 feet. Hard clayey silt was then encountered to 50 feet deep.
- **Bridge BR No. 39-141, Merced:** Very dense silty sand in the upper 5 feet, underlain by medium dense to dense silty fine sand to a depth of approximately 30 feet. Dense to very dense sand was then encountered to a depth of 38 feet, underlain by very hard silt to the bottom of the boring at 45 feet.
- **Campus Park Overhead:** Medium dense to very dense silty sand and stiff to very stiff silt in the upper 50 feet, underlain by hard lean clay and very stiff silt extending down to about 100 feet deep, were encountered at the Campus Park Bridge location.
- **SE Corner of Hwy 140 and Plainsburg, Planada:** In this area soils consist of silty clay in the upper 10 feet, underlain by gravel, sand and silty sand to a depth of about 30 feet. Soil consistency was not indicated in the boring logs.
- **9290 East Highway 140, Planada:** The soil profile for this location is sandy lean clay in the upper 5 feet, underlain by medium dense to very dense sand and silty sand extending down to about 35 feet deep.
- **9261 Broadway, Planada:** Interbedded layers of clays and sandy silt in the upper 15 feet at this location; soil consistency was not indicated in the boring logs.
- **Le Grand Union High School:** Medium dense silty sand with pebbles was encountered in the upper 10 feet, underlain by dense to very dense gravels/cobbles to depths of 20 to 25 feet.
- **Chowchilla River Bridge (Santa Fe Drive Bridge across Chowchilla River):** Very loose sand and sandy silt in the upper 10 feet, underlain by medium dense sand to 25 feet. These soils were underlain by loose sandy silt to a depth of about 30 feet. Medium dense clayey sand was

encountered to a depth of about 35 feet, underlain by very dense sandy gravel and sandy silt to a depth of about 50 feet.

- **Berenda Slough Bridge (Santa Fe Drive over Berenda Slough):** Very loose silty sands in the upper 15 feet, underlain by compact, medium dense to dense silty sands or clayey sands to a depth of 60 feet, underlain by very stiff to hard clayey silt to 70 feet. These soils were underlain by dense sandy silts to a depth of approximately 80 feet.
- **28274 Avenue 13½, Madera:** Medium dense to dense sand/silty sand occur in the upper 80 feet, with interbedded layers of medium dense to dense sandy silt or hard clayey silt.
- **SR 99 San Joaquin River Bridge (Bridge No. 41-0008):** Subsurface soils consist mainly of dense sand to hard sandy silt with intermediate layers of very stiff sandy clay to the maximum depth explored of approximately 90 feet.

Hybrid Alternative

As described in Section 2, Project Description, the Hybrid Alternative combines alignments of the UPRR/SR 99 and BNSF alternatives and design options. Therefore, it has the characteristics of the UPRR/SR 99 alternative from the Downtown Merced Station to Chowchilla, where it transitions to the BNSF alignment. The switch from the UPRR/SR 99 to the BNSF alignments occurs in the vicinity of Berenda Creek. Descriptions given above for UPRR/SR 99 north of Berenda Creek are the same for the north end of the Hybrid Alternative and after the transition along the Ave 24 Wye, those for the BNSF are appropriate.

Ave 24 and Ave 21 Wyes

- **Ave 24 Wye over SR 99 Bridge (Bridge No 41-0054):** Medium dense to dense sand layers with few silty clay and silty sand pockets to the maximum depth explored of approximately 65 feet bgs.
- **Ave 21 Wye over Ash Slough Bridge:** Medium dense sandy silt in the upper 25 feet, underlain by loose to medium dense sand and sandy silt to a depth of about 45 feet, underlain by medium dense sand to 50 feet deep.

Because most soils within the study area are mapped as alluvial soils, the soils underlying the alignments of the three alternatives, the wyes, the stations, and the HMF sites are most likely similar to the soils encountered at the locations summarized above in that they would consist of clay, silt, sand, and gravel of varying content and characterized by variations in consistency.

3.5.2.2 Groundwater Conditions

General depths to groundwater were obtained from groundwater contour maps from various years (1982, 1990, 2000, and 2002). Depth to groundwater varies from 0 to 190 feet bgs in the study area. The groundwater information for different years also indicates that the depth to groundwater can vary considerably (about 20 feet or more) each season, depending on rainfall conditions. Groundwater is typically shallower toward the northern and southern ends of the UPRR/SR 99 and BNSF Alternatives and is deepest between the cities of Chowchilla and Madera. Groundwater is also generally deeper toward the northeast part of the study area and becomes shallower toward the southwest part. Table 3-6 provides a summary of groundwater depths at different locations along the alignments.

Table 3-6
 Summary of General Groundwater Depths

Location	Groundwater Depth (feet)
Atwater to Merced Area	0 to 50
Downtown Merced Station Area	50
Merced to Chowchilla Area	50 to 100
Chowchilla Area	38 to 75 ^a
Chowchilla to Madera Area	150 to 190
Madera Area	100 to 150
Madera to Fresno, Downtown Fresno Station Area	50 to 100
^a Advanced Environmental Concepts (2004). Source: California Department of Water Resources (2000)	

3.6 Soils along Proposed HST Alternatives

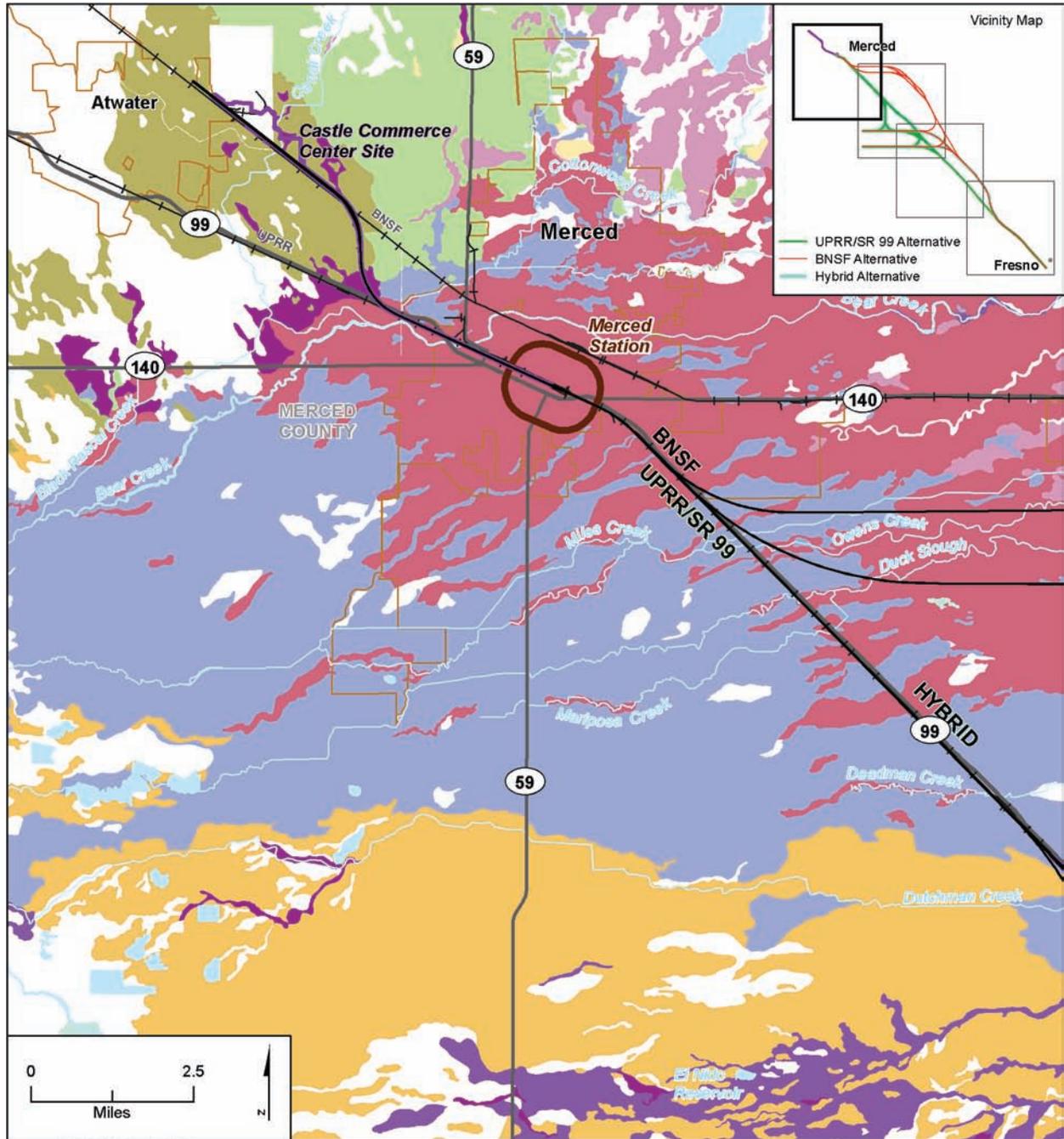
NRCS soil surveys were used to gather information about soils associated with the HST alternatives, including the north-south alignments, wyes, stations, and HMFs. This soils information is generally based on conditions within the upper 4 to 5 feet of the ground surface; however, these surficial soil survey conditions can extend to greater depths, though the possibility of changes in soil types would increase. This section summarizes the discussion in the previous section, but focuses on near-ground-surface issues such as erosion, shrink/swell characteristics, and corrosion potential. Soil survey information is typically published by county or geographic area; the soil surveys used for this project were of the Eastern Fresno area (NRCS 1971), Madera area (NRCS 1962a), and Merced area (NRCS 1962b).

3.6.1 Soil Associations for All Alternatives

NRCS soil surveys contain soils information by soil associations and map units. Soil associations are groups of map units that occur together in a landscape. Soil and map units differ in terms of the scale of the survey area:

- Soil associations are typically named after the two or three dominant soil series in the association (e.g., the dominant soil components in the Pachappa-Grangeville association in Merced County are the Pachappa and Grangeville soil series), and are developed for each individual soil survey area. Soil associations are useful for comparing the general suitability of large areas for a specific land use.
- Map units are useful for evaluating soil suitability on a more-local scale, particularly for those physical processes or responses that are associated with soil behavior in the upper 4 to 5 feet, such as shallow foundations, shrink/swell characteristics, and corrosivity.

Figures 3-5 through 3-8 shows the soil associations in the study area. Table 3-7 identifies the soil associations for the four landform groups that NRCS identified within the study area (recent alluvial fans and floodplains; older, low alluvial terraces; basin areas, including saline-alkali basins; and high terraces) and the counties in which they are located. Table 3-8 summarizes the predominant surface soil associations along each of the HST alternatives. Tables 3-9 and 3-10 list the soil associations by alternative and by HMF, respectively.

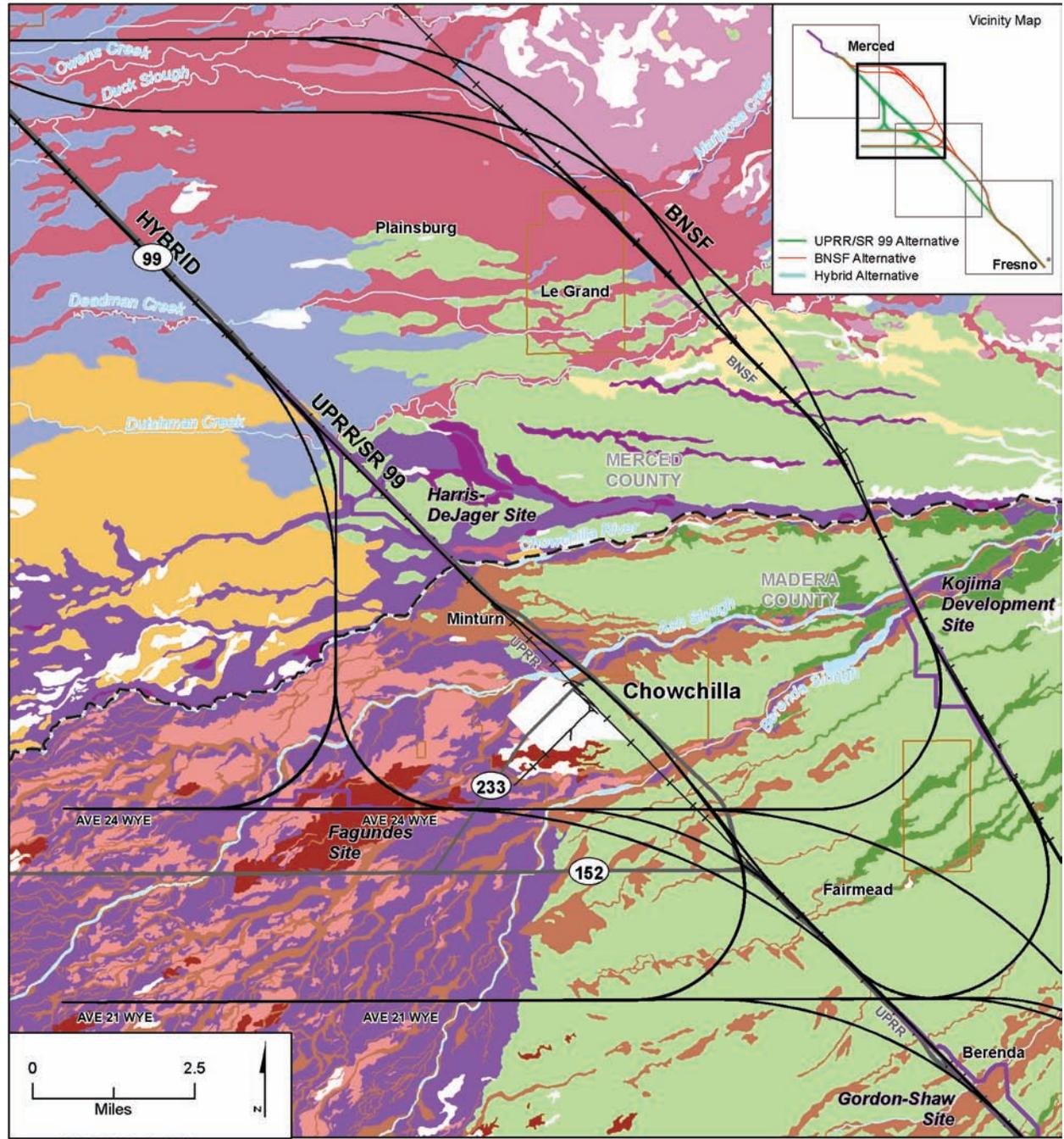


Source: NRCS (1962a, b, 1971).

MF_EIS_GS_17-20_a Jun 29, 2011

- | | | |
|--|---|--|
| <ul style="list-style-type: none"> — HST Alignment □ Potential Heavy Maintenance Facility ○ Station Study Area □ City Limit - - - County Boundary + + Railroad | <p>Merced County Associations</p> <ul style="list-style-type: none"> Delhi-Atwater association Fresno-Traver association Hanford-Grangeville association Lewis-Landlow-Burchell association Pachappa-Grangeville association Redding-Pentz-Peters association Rossi-Waukena association San Joaquin-Madera association Whitney-Rocklin-Montpellier association Wyman-Yokohl-Marguerite association | <p>Madera County Associations</p> <ul style="list-style-type: none"> Cometa-Whitney association Fresno-El Peco association Hanford-Tujunga association Pachappa-Grangeville association San Joaquin-Madera association Traver-Chino association <p>Fresno County Associations</p> <ul style="list-style-type: none"> Greenfield-Atwater association Hanford-Delhi-Hesperia association Hanford-Hesperia association Hanford-Tujunga association San Joaquin-Exeter-Ramona association |
|--|---|--|

Figure 3-5
 Soil Associations within
 the Merced Project
 Vicinity

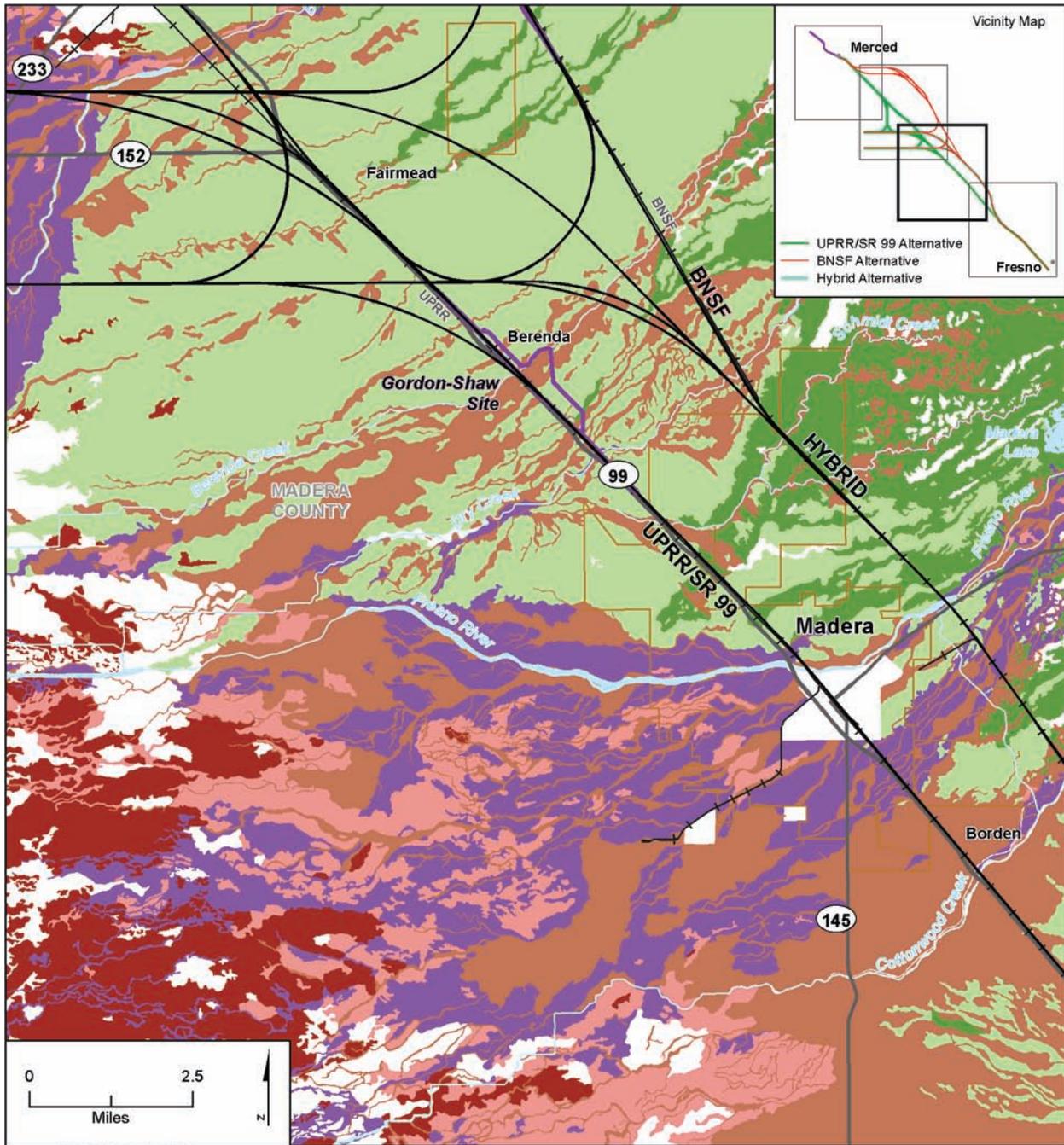


Source: NRCS (1962a, b, 1971).

MF_EIS_GS_17-20_b Jun 29, 2011

- | | | |
|--|---|--|
| <ul style="list-style-type: none"> — HST Alignment □ Potential Heavy Maintenance Facility ○ Station Study Area □ City Limit - - - County Boundary + + Railroad | <p>Merced County Associations</p> <ul style="list-style-type: none"> Delhi-Atwater association Fresno-Traver association Hanford-Grangeville association Lewis-Landlow-Burchell association Pachappa-Grangeville association Redding-Pentz-Peters association Rossi-Waukena association San Joaquin-Madera association Whitney-Rocklin-Montpellier association Wyman-Yokohi-Marguerite association | <p>Madera County Associations</p> <ul style="list-style-type: none"> Cometa-Whitney association Fresno-El Peco association Hanford-Tujunga association Pachappa-Grangeville association San Joaquin-Madera association Traver-Chino association <p>Fresno County Associations</p> <ul style="list-style-type: none"> Greenfield-Atwater association Hanford-Delhi-Hesperia association Hanford-Hesperia association Hanford-Tujunga association San Joaquin-Exeter-Ramona association |
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Figure 3-6
 Soil Associations within
 the Chowchilla Project
 Vicinity

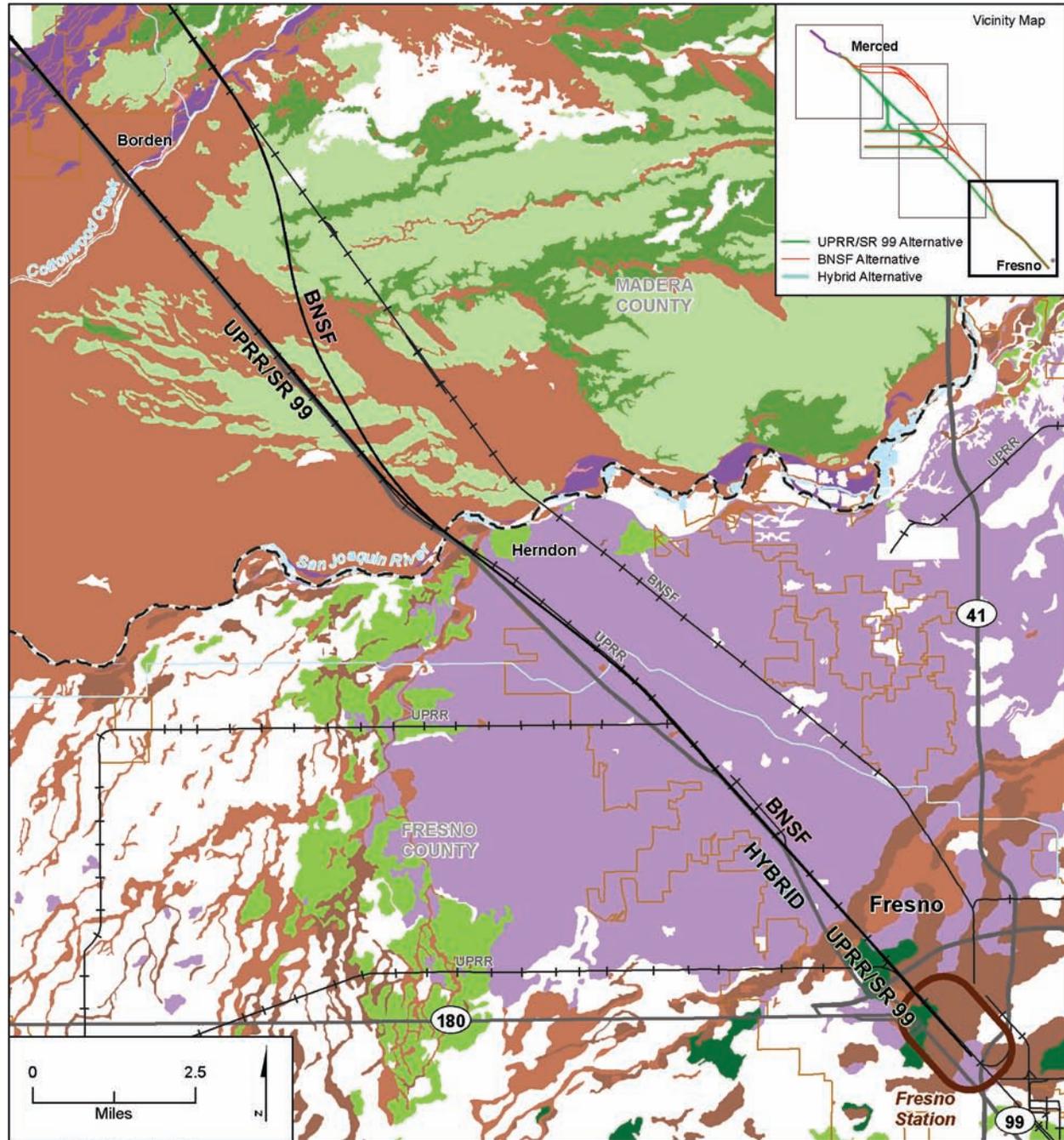


Source: NRCS (1962a, b, 1971).

MF_EIS_GS_17-20_c Jun 29, 2011

- | | | |
|--|---|--|
| <ul style="list-style-type: none"> — HST Alignment ▭ Potential Heavy Maintenance Facility ⊙ Station Study Area ▭ City Limit - - - County Boundary + + Railroad | <p>Merced County Associations</p> <ul style="list-style-type: none"> Delhi-Atwater association Fresno-Traver association Hanford-Grangeville association Lewis-Landlow-Burchell association Pachappa-Grangeville association Redding-Pentz-Peters association Rossi-Waukena association San Joaquin-Madera association Whitney-Rocklin-Montpellier association Wyman-Yokohl-Marguerite association | <p>Madera County Associations</p> <ul style="list-style-type: none"> Cometa-Whitney association Fresno-El Peco association Hanford-Tujunga association Pachappa-Grangeville association San Joaquin-Madera association Traver-Chino association <p>Fresno County Associations</p> <ul style="list-style-type: none"> Greenfield-Atwater association Hanford-Delhi-Hesperia association Hanford-Hesperia association Hanford-Tujunga association San Joaquin-Exeter-Ramona association |
|--|---|--|

Figure 3-7
 Soil Associations within
 the Madera Project
 Vicinity



Source: NRCS (1962a, b, 1971).

MF_EIS_GS_17-20_d Jun 29, 2011

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| <ul style="list-style-type: none"> — HST Alignment □ Potential Heavy Maintenance Facility ○ Station Study Area □ City Limit - - - County Boundary + + Railroad | <p>Merced County Associations</p> <ul style="list-style-type: none"> Delhi-Atwater association Fresno-Traver association Hanford-Grangeville association Lewis-Landlow-Burchell association Pachappa-Grangeville association Redding-Pentz-Peters association Rossi-Waukena association San Joaquin-Madera association Whitney-Rocklin-Montpellier association Wyman-Yokohi-Marguerite association | <p>Madera County Associations</p> <ul style="list-style-type: none"> Cometa-Whitney association Fresno-El Peco association Hanford-Tujunga association Pachappa-Grangeville association San Joaquin-Madera association Traver-Chino association <p>Fresno County Associations</p> <ul style="list-style-type: none"> Greenfield-Atwater association Hanford-Delhi-Hesperia association Hanford-Hesperia association Hanford-Tujunga association San Joaquin-Exeter-Ramona association |
|--|---|--|

Figure 3-8
 Soil Associations within
 the Fresno Project
 Vicinity

Table 3-7
 Summary of Soil Associations

Soil Association	Counties of Occurrence	Landform Groups ^a	Soil Hazards
Pachappa-Grangeville association	Merced, Madera	Recent alluvial fans and floodplains	<ul style="list-style-type: none"> • low shrink-swell potential • moderately to highly corrosive to uncoated steel • slightly corrosive to concrete • moderate potential for water erosion • high potential for wind erosion
Hanford-Tujunga association	Madera, Fresno		
Hanford-Grangeville association	Merced		
Wyman-Yokohl-Marguerite association	Merced		
Hanford-Hesperia association	Fresno		
Hanford-Delhi-Hesperia association	Fresno		
Greenfield-Atwater association	Fresno		
Delhi-Atwater association	Merced		
San Joaquin-Madera association	Merced	Older, low alluvial terraces	<ul style="list-style-type: none"> • high shrink-swell potential • highly corrosive to uncoated steel • moderately corrosive to concrete • moderate potential for water erosion • high potential for wind erosion
San Joaquin-Exeter-Ramona association	Fresno		
San Joaquin-Madera association	Madera		
Cometa-Whitney association	Madera		
Fresno-Traver association	Merced	Basin areas (including saline-alkali basins)	<ul style="list-style-type: none"> • moderate shrink-swell potential • highly corrosive to uncoated steel • moderately corrosive to concrete • high potential for water erosion • moderate to high wind erosion potential
Lewis-Landlow-Burchell association	Merced		
Fresno-El Peco association	Madera		
Traver-Chino association	Madera		
Rossi-Waukena association	Merced		
Whitney-Rocklin-Montpellier association	Merced	High terraces	<ul style="list-style-type: none"> • moderate to high shrink-swell potential • highly corrosive to uncoated steel • moderately corrosive to concrete • moderate potential for water erosion • low to high potential for wind erosion
Redding-Pentz-Peters association	Merced		

^aAs mapped by NRCS, not necessarily observed in the study area.
 Sources: NRCS (1962a, 1962b, 1971)

Table 3-8
 Predominant Soil Associations between the City of Merced and the City of Fresno

Location	UPRR/SR 99 Alternative	BNSF Alternative	Hybrid Alternative
Merced	Wyman-Yokohl-Marguerite Association	Wyman-Yokohl-Marguerite Association	Wyman-Yokohl-Marguerite Association
Merced to Chowchilla	Lewis-Landlow-Burchell Association	Wyman-Yokohl-Marguerite Association and Redding-Penz-Peters Association	Lewis-Landlow-Burchell Association
Chowchilla	San Joaquin-Madera Association	San Joaquin-Madera Association	San Joaquin-Madera Association
Ave 24 and 21 Wyes	San Joaquin-Madera Association with some Hanford-Tujunga Association	San Joaquin-Madera Association	Traver-Chino Association and Pachappa-Grangeville Association
Chowchilla to Madera	San Joaquin-Madera Association	San Joaquin-Madera Association with some Cometa-Whitney Association	San Joaquin-Madera Association with some Cometa-Whitney Association
Madera to Fresno County Line	San Joaquin-Madera Association and Pachappa-Grangeville Association and Hanford-Tujunga Association	San Joaquin-Madera Association and Cometa-Whitney Association with some Pachappa-Grangeville Association and Hanford-Tujunga Association	San Joaquin-Madera Association and Cometa-Whitney Association with some Pachappa-Grangeville Association and Hanford-Tujunga Association
County Line to Fresno	San Joaquin-Exeter-Ramona Association	San Joaquin-Exeter-Ramona Association	San Joaquin-Exeter-Ramona Association

Table 3-9
 Soil Associations within Each Alternative

Soil Association	UPRR/SR 99 Alternative					BNSF Alternative			Hybrid Alternative		
	North-South Alignment	Ave 24 Wye	Ave 21 Wye	Downtown Merced Station	Downtown Fresno Station	North-South Alignment	Ave 24 Wye	Ave 21 Wye	North-South Alignments	Downtown Merced Station	Downtown Fresno Station
Merced County Soil Associations											
Delhi-Atwater	✓					✓			✓		

Soil Association	UPRR/SR 99 Alternative					BNSF Alternative			Hybrid Alternative		
	North-South Alignment	Ave 24 Wye	Ave 21 Wye	Downtown Merced Station	Downtown Fresno Station	North-South Alignment	Ave 24 Wye	Ave 21 Wye	North-South Alignments	Downtown Merced Station	Downtown Fresno Station
Fresno-Traver	✓	✓							✓		
Hanford-Grangeville	✓	✓				✓			✓		
Lewis-Landlow-Burchell	✓	✓				✓			✓		
Pachappa-Grangeville		✓				✓					
San Joaquin-Madera		✓				✓					
Wyman-Yokohl-Marguerite	✓			✓		✓			✓	✓	
Rossi-Waukena						✓					
Whitney-Rocklin-Montpellier						✓					
Redding-Pentz-Peters						✓					
Madera County Soil Associations											
Cometa-Whitney	✓					✓	✓	✓			
Fresno-El Peco		✓							✓		
Hanford-Tujunga	✓	✓	✓			✓	✓	✓	✓		
Pachappa-Grangeville	✓	✓	✓			✓		✓	✓		
San Joaquin-Madera	✓	✓	✓			✓	✓	✓	✓		

Soil Association	UPRR/SR 99 Alternative					BNSF Alternative			Hybrid Alternative		
	North-South Alignment	Ave 24 Wye	Ave 21 Wye	Downtown Merced Station	Downtown Fresno Station	North-South Alignment	Ave 24 Wye	Ave 21 Wye	North-South Alignments	Downtown Merced Station	Downtown Fresno Station
Traver-Chino	✓	✓	✓					✓	✓		
Fresno County Soil Associations											
Greenfield-Atwater	✓				✓	✓			✓		✓
Hanford-Delhi-Hesperia	✓				✓	✓			✓		✓
Hanford-Hesperia	✓					✓			✓		
Hanford-Tujunga	✓				✓	✓			✓		✓
San Joaquin-Exeter-Ramona	✓				✓	✓			✓		✓
Notes: Refer to Figures 3-5 through 3-8 for locations of soil associations.											

Table 3-10
Soil Associations within Each HMF Site

Soil Association	Castle Commerce Center	Harris-DeJager	Fagundes	Gordon-Shaw	Kojima
Merced County Soil Associations					
Delhi-Atwater	✓				
Fresno-Traver					
Hanford-Grangeville	✓				
Pachappa-Grangeville		✓			
San Joaquin-Madera		✓			
Wyman-Yokohl-Marguerite		✓			
Madera County Soil Associations					
Cometa-Whitney				✓	✓

Soil Association	Castle Commerce Center	Harris-DeJager	Fagundes	Gordon-Shaw	Kojima
Fresno-El Peco			✓		
Hanford-Tujunga			✓	✓	✓
Pachappa-Grangeville			✓		✓
San Joaquin-Madera				✓	✓
Traver-Chino			✓		
Notes: Refer to Figures 3-5 through 3-8 for locations of soil associations. Fresno County soil associations are not shown for the HMFs because there are no HMFs located in Fresno County.					

3.6.2 Landform Groups and Soils Characteristics

Affected landform groups and their associated soil characteristics are described below. These descriptions provide a general indication of soil texture, drainage, shrink/swell potential, corrosivity, and erosion susceptibility for each member of the association.

3.6.2.1 Recent Alluvial Fans and Floodplains

Soils of the recent alluvial fans and floodplains developed in the nearly level and gently sloping areas along drainage ways, on alluvial fans, and on floodplains. Characteristics often vary greatly within short distances because these soils formed from stratified stream deposits. Within the affected area, these soils are medium- to coarse-textured (low amount of clay), and are generally well to somewhat excessively drained (that is, they transmit water well and do not pond). Most of these soils are very deep, but some areas may have compacted silt or sand or an iron-silica hardpan 2 to 4 feet bgs. Some areas are slightly to moderately saline and alkaline at depths of 4 to 5 feet.

Soils of the recent alluvial fans and floodplains generally do not contain a substantial amount of expansive clay and therefore have a low shrink-swell potential. These soils are moderately to highly corrosive to uncoated steel and are only slightly corrosive to concrete. The medium-to-coarse textures of these soils make them susceptible to erosion. These soils have a moderate potential for water erosion and a high potential for wind erosion if not properly covered or stabilized after disturbance.

3.6.2.2 Older, Low Alluvial Terraces

Soils formed on older, low alluvial terraces tend to have a greater degree of soil development than soils on recent alluvial fans. Low alluvial terraces typically have undulating to rolling topography, and may have relatively steep slopes in some areas. The soils are medium-textured and typically have a strongly cemented or indurated hardpan in the subsoil (from 12 to 48 inches bgs). The hardpan can be composed of cemented silica or clay; either type creates a layer that is restrictive to roots and water and can create a perched water table.

The soils of the older, low alluvial terraces contain expansive clays, giving these soils a high shrink-swell potential. These soils are highly corrosive to uncoated steel and moderately corrosive to concrete. These soils may have a moderate potential for water erosion and a high potential for wind erosion if not properly covered or stabilized after disturbance.

3.6.2.3 Basin Areas (including Saline-Alkali Basins)

Basin area soils developed from fine-textured, water-transported sediments and water-soluble lime and salts. The topography of these areas is nearly level to gently undulating. Soils are finer-textured (have more clay) than the alluvial and high terrace soils, and nearly all have accumulations of salts and alkali as a result of poor drainage (water is not transmitted well through the soil and tends to pond). Most of these soils have cemented lime-silica hardpan layers in the upper 4 to 5 feet and are shallow to moderately deep (i.e., upper 4 to 5 feet).

Although basin soils generally have greater clay content than the alluvial terrace and high terrace soils, they have only a moderate shrink-swell potential because they contain fewer expansive clays. These soils are highly corrosive to uncoated steel and are moderately corrosive to concrete. The potential for water erosion of these soils is high, and wind erosion potential is moderate to high if the soils are not properly covered or stabilized after disturbance.

3.6.2.4 High Terraces

Soils of the high terraces are older than the soils of the other associations and tend to be strongly weathered. Much of the study area is dissected into low hills, resulting in an undulating landscape dominated by mound relief. High terrace soils are coarser than alluvial terrace and basin soils, with textures ranging from fine sandy loam to gravelly loam. Some of the high terrace soils are underlain by an iron-silica hardpan or claypan, both of which may restrict drainage.

Although the soils of the high terraces tend towards coarser textures, they have a moderate to high potential for shrinking and swelling. These soils are highly corrosive to uncoated steel and are moderately corrosive to concrete. The potential for water erosion is moderate, and the potential for wind erosion varies from low to high, depending on surface textures.

3.7 Geologic Hazards

A geologic hazard area is defined as an area that poses a potential threat to the health and safety of citizens when incompatible commercial, residential, or industrial developments are located in areas of significant geologic hazard. Two broad categories of geologic hazards exist: seismic and non-seismic. The following discussion covers two types of non-seismic hazards that could be considerations for the HST alternatives: landslides and subsidence. Other typical types of non-seismic hazards, such as rockfalls and steep slopes, are not addressed because they are not relevant to the HST project. Seismic-related geologic hazards are discussed in the Section 3.8, Primary Seismic Hazards, and Section 3.9, Secondary Seismic Hazards.

3.7.1 Landslide Hazards

Landslides occur in areas of moderate-to-steep topography (e.g., slopes greater than 3H:1V) and where the combination of soil, rock, and groundwater conditions results in ground movement. Landslides can be initiated by rainfall, earthquakes, volcanic activity, changes in groundwater, disturbance, change of a slope by man-made construction activities, or any combination of these factors.

Landslide inventories and landslide hazard maps developed by CGS and USGS were not available for the study area; therefore, topographic maps of the study area were reviewed to evaluate the potential for existing and future landslides. The absence of CGS and USGS landslide inventories and landslide hazard maps is by itself indicative of the lack of landslide hazard, because neither the state nor federal agency consider the area to have topographic conditions that could lead to landslide hazards. Fresno County (2000b) reported that surficial slides and slumps may occur along the steep banks of rivers and creeks.

Results of the topography review confirmed that the topography within and adjacent to the HST alternatives, including the north-south alignments, wyes, stations, and HMFs, is relatively flat, with only localized areas of steep slopes, defined for this project as slopes taller than 15 feet and steeper than

2H:1V (horizontal to vertical), or 27 degrees. These steep slopes are typically located adjacent to rivers and creeks. According to topographic maps, there are three locations where the slopes are 15 feet tall or taller:

- At the San Joaquin River crossing, where slopes are about 50 feet tall for the three alternatives,
- At the Fresno River crossing for the BNSF and Hybrid alternatives where the slopes are about 15 feet, and
- At the Berenda Creek crossing, where slopes for all three alternatives are about 15 to 20 feet tall.

The overall flat topography and only a few locations of steep banks along the rivers makes the risk of landslides and surficial slides and slumps low along the project alignments.

3.7.2 Land Subsidence

Land subsidence is a form of ground settlement that usually results from change in fluid content within soil or rock. The volume change can result from localized dewatering of peat, organic soils, or soft silts and clay. This type of ground settlement is often associated with construction activities, when groundwater is lowered to allow construction below the groundwater table. The other form of land subsidence is from a regional withdrawal of groundwater, petroleum, or geothermal resources. Regional subsidence can also result from vertical fault movement, which is discussed in Section 3.8.3, Surface Fault Rupture. Although the mechanism is different, another cause of land subsidence is the ongoing decomposition of organic-rich soils. This type of subsidence generally occurs in localized areas and does not appear to be prevalent along the alignment.

Water extraction has been the main cause of subsidence in the San Joaquin Valley. Between 1926 and 1970, portions of the San Joaquin Valley subsided more than 28 feet after water extraction; however, the area of the HST alternatives, including the north-south alignments, wyes, stations, and HMF, subsided less than 1 foot during this time (Galloway and Riley 1999). Since 1974, land subsidence caused by water extraction has greatly slowed or stopped in the San Joaquin Valley, as state agencies and landowners became aware of the consequences of water withdrawals. Unless there is a change in agency policies, there is little risk of large-scale land subsidence along the HST alternatives. There is, however, a moderate risk of small, localized areas of subsidence, or settlement, from construction-related dewatering of excavations.

3.8 Primary Seismic Hazards

Primary seismic hazards assessed for this report are surface fault rupture transecting the alignment(s) and ground shaking. Active faulting is prevalent throughout California, and these faults can undergo feet of movement when they rupture. When faults rupture, they also create ground shaking that can be felt hundreds of miles from the source. This section describes the seismic setting for the study area, identifies active and potentially active faults in the vicinity of the project, discusses the surface fault rupture potential relative to the alignments, and summarizes the level of potential ground shaking that must be considered for design.

3.8.1 Seismic Setting

The HST alternatives, including the north-south alignments, wyes, stations, and HMFs, are located in an area that has been subject to past earthquake ground shaking and that will undergo earthquake ground shaking again in the future. The earthquakes of California are primarily caused by the movement of huge blocks of the earth's crust, the Pacific and North American plates. The Pacific plate is moving northwest, scraping horizontally past the North America plate at an overall average rate of about 2 inches per year. The primary boundary between the two tectonic plates is the San Andreas fault, which is more than 650 miles long and extends 10 miles deep.

Movement is not constant in portions of the San Andreas fault system, and strain can build up for hundreds of years, resulting in strong earthquakes when the strain is released. In the central segment of the San Andreas fault, the segment closest to the area of the HST alternatives, which is about 65 miles west of the nearest alternative alignment, the movement is a constant “creep” that results in more frequent, but moderate, earth tremors.

As a byproduct of this large-scale plate movement, additional faults have developed in the Pacific and North American plates in response to the accumulation of stresses and strains. These crustal faults serve as sources of seismic events, and consequent fault displacement and ground motions. There is historic evidence of six earthquakes in the past 130 years that resulted in significant shaking within the broader study area: events in 1872 (Lone Pine M7.6), 1906 (San Francisco M8.3), 1952 (Kern County M7.7), 1966 (Parkfield M6.0), 1984 (Morgan Hill M6.1), and 1989 (Loma Prieta M7.1) (Merced County 2007, Ellsworth 1990). The epicenters of these earthquakes did not occur within the study area but were in the surrounding region. Figure 3-9 shows locations of historical earthquakes and their magnitudes in the region for seismic events with magnitudes equal to 7.9 or less.

Active and potentially active faults have been identified in the San Joaquin Valley and the surrounding region west and east of the valley. A seismic event along any of these faults or fault zones, depending on type and exposure, can result in permanent offsets at the ground surface along the fault line, and, depending on proximity to the event epicenter, varying degrees of ground shaking.

3.8.2 Active and Potentially Active Faults

A conservative criterion was adopted for assessing surface rupture hazard in the study area because of the extreme disruption that could occur to transit facilities resulting from surface rupture along the proposed alignments. This criterion considers both active and potentially active faults. An active fault is defined as a ground rupture that has occurred within the last 11,000 years or so. A potentially active fault includes ruptures that occurred between 11,000 and 1.6 million years ago (Hart and Bryant 1999).

Figure 3-10 shows active and potentially active fault locations mapped by CGS and USGS within an approximate 65-mile radius of the study area, and Table 3-11 provides supporting data for these faults. Figure 3-10 shows that there are no active or potentially active faults known to transect or can be projected to transect the HST north-south alignments or the HMF sites. This means that the potential for disruption of the alternatives from earthquake-induced fault displacement is extremely low, and even could be said to be nonexistent based on currently available information.

An earthquake on one of these source mechanisms, as well as other similar faults located throughout central California, would likely result in vibratory ground motions within the areas of the HST alternatives, including the north-south alignments, wyes, stations, and HMFs. The level of ground shaking will depend on a combination of the size, or magnitude, of the earthquake and the distance from the earthquake epicenter and the study area. The magnitude of the earthquake is generally associated with the length of the fault: longer faults produce more energy, which causes larger ground motions at a given distance. The level of shaking from a seismic event on one of the nearby faults shown in Figure 3-4 would be relatively small because of either the distance to the fault or the maximum size of the seismic event that can be associated with the fault. Because of its much longer length, the San Andreas Fault could, however, result in relative strong ground shaking within the study area.

CGS and USGS have identified two nearby active or potentially active faults that could be the source of future strong ground motions:

- The nearest active fault, mapped by CGS (2009), is the Ortigalita Fault Zone, about 34 miles west of the nearest alignment, for the UPRR/SR 99 Alternative. USGS classifies the Ortigalita Fault Zone as Class A. USGS believes this fault is the source of magnitude 6 or greater earthquakes during the Quaternary (the past 1.6 million years). The maximum credible earthquake (MCE) for the Ortigalita Fault Zone is 7.0 (Caltrans 1996), and the recurrence interval for the entire Ortigalita Fault Zone is estimated to be 2,000 to 5,000 years (Bryant and Cluett 2000).

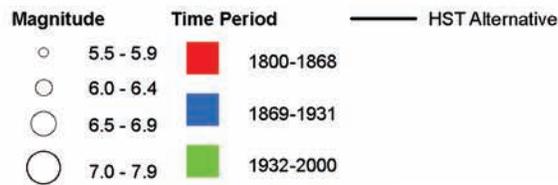
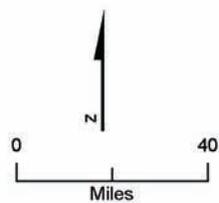
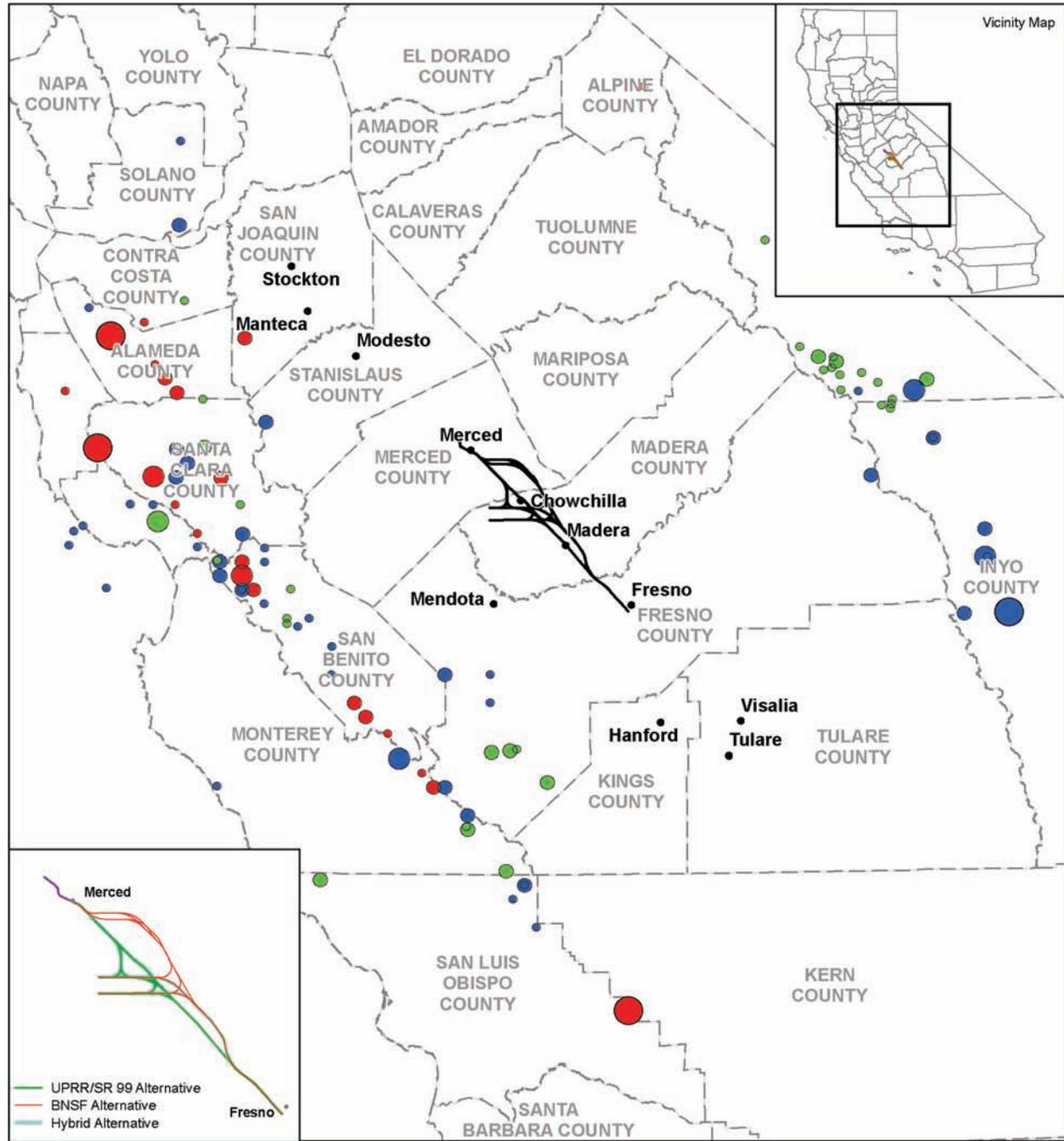
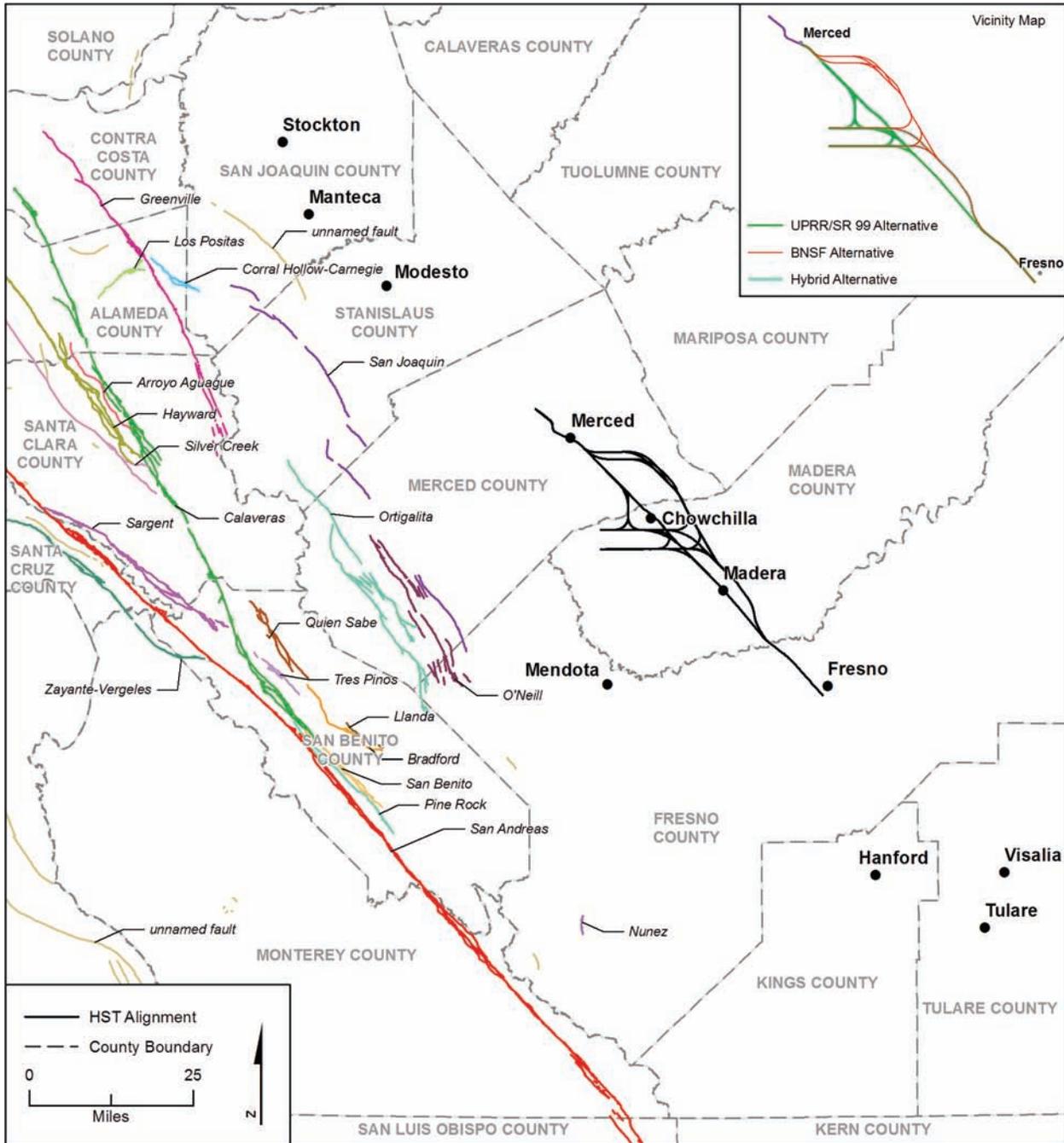


Figure 3-9
 Historical Earthquakes and Magnitudes
 within 100 Miles of Project Area



Source: USGS and GCS 2006

MF_EIS_GS_02 Jun 03, 2011

- | | | |
|--------------------------------|--------------------------|-------------------------------|
| — Arroyo Aguague fault | — Los Positas fault | — San Joaquin fault |
| — Bradford fault | — Nunez fault | — Sargent fault zone |
| — Calaveras fault zone | — O'Neill fault system | — Silver Creek fault zone |
| — Corral Hollow-Carnegie fault | — Ortigalita fault zone | — Tres Pinos fault |
| — Dog Valley fault zone | — Pine Rock fault zone | — Zayante-Vergeles fault zone |
| — Greenville fault zone | — Quien Sabe fault zone | — Unnamed fault |
| — Hayward fault zone | — San Andreas fault zone | — County Boundary |
| — Llanda fault | — San Benito fault zone | |

Figure 3-10
 Active and Potentially Active Faults within
 about 65 miles of the HST Alternatives

- The nearest fault zone mapped by USGS and CGS (2009) and CGS (2010) is the San Joaquin Fault Zone, about 25 miles west of the nearest alternative alignment, for the UPRR/SR 99 Alternative. The San Joaquin Fault Zone is considered potentially active, and USGS believes this fault is the source of magnitude 6 or greater earthquakes during the Quaternary. The MCE for the San Joaquin Fault Zone is 6.5 to 6.75 (Caltrans 1996), with a recurrence interval of 1,000 years (Wesnousky 1986).

One other fault, the Clovis Fault, was identified in the immediate vicinity of the alternative alignments. The Clovis Fault is an inferred northwest-trending fault, believed to be located approximately 5 to 6 miles east of the City of Clovis, extending from just south of the San Joaquin River to a few miles south of Fancher Creek, approximately 6 miles northeast of the alternative alignments. The Clovis Fault is reported as potentially active by Madera County (1995b); however, Fresno County (2000b) reports it to be a pre-Quaternary fault with no recognizable movement during the Quaternary, but not necessarily an inactive fault. The Clovis Fault is not mapped as an active fault (CGS 2009) or a Class A or Class B fault (USGS and CGS 2009); therefore, it is not considered active or potentially active by either the USGS or CGS and is not shown on Figure 3-10.

In the above discussions Caltrans defined the MCE as the largest hypothesized earthquake reasonably capable of occurring, based on current geological knowledge, rather than as the maximum considered earthquake used in current codes.

Table 3-11
 Active and Potentially Active Faults within 65 Miles of the HST Alternatives

USGS Fault No.	Fault Name	Closest Distance to HST Alternatives (mi) ^a	Fault Type	Estimated Mapped Length (mi) ^b	Most Recent Deformation ^c	Slip Rate (in per yr) ^d
403	San Joaquin fault zone	25	NI	203	<130 ka	NI
372	O'Neill fault system	30	NI	27	<130 ka	NI
52	Ortogonalita fault zone	34	Right lateral	44	<15 ka	0.04-0.2
27	Foothills fault system	35	Strike-slip?	127	<130 ka	NI
N/A	Unnamed fault 13 mi (21 km) west of Modesto	38	NI	21	<1.6 Ma	<0.008
N/A	Unnamed fault 19 mi (31 km) southwest of Mendota	41	NI	2	<1.6 Ma	<0.008
N/A	Panoche Hills fault	43	NI	7	<1.6 Ma	<0.008
53	Greenville fault zone	45	Right lateral	57	<15 ka and <1.6 Ma	0.008-0.04
369	Arroyo Aguague fault	46	Reverse	16/26	<1.6 Ma	<0.008
242	Corral Hollow-Carnegie fault zone	53	NI	9	<15 ka and <1.6 Ma	<0.008

USGS Fault No.	Fault Name	Closest Distance to HST Alternatives (mi) ^a	Fault Type	Estimated Mapped Length (mi) ^b	Most Recent Deformation ^c	Slip Rate (in per yr) ^d
289	Nunez/Los Positos fault	53	Right lateral, reverse	3	<150 years	Unknown
64	Quien Sabe fault	54	Right lateral, normal	15	<150 years to <1.6 Ma	0.008-0.04
58	Sargent fault zone	56	Right lateral	34	<150 years and <15 ka	0.04-0.2
405	Llanda fault	57	NI	7	<1.6 Ma	<0.008
237	Silver Creek fault zone	58	Right lateral, reverse	37	<1.6 Ma	<0.008
406	Tres Pinos	58	Right lateral	10	<1.6 Ma	<0.008
404	Bradford fault	58	NI	16	< 1.6 Ma	<0.008
55	Hayward fault zone	59	Right lateral	66	< 150 years, <15 k, <130 ka	0.04-0.2
288	San Benito fault zone	60	NI	17	<1.6 Ma	<0.008
54	Calaveras fault zone	60	Reverse, right lateral	97	<15 ka	>0.2
287	Pine Rock fault zone	62	Right lateral	23	<130 ka	Unknown
N/A	Unnamed fault 12 mi (19 km) west of Coalinga	62	NI	3	<1.6 Ma	<0.008
239	Los Positas	63	Strike slip	9	< 150 years and <130 ka	Unknown
1	San Andreas fault zone	65	Right lateral	672	<150 years	>0.2
59	Zayante-Vegeles fault zone	65	Right lateral, reverse	54	<130 ka	0.008-0.04

USGS Fault No.	Fault Name	Closest Distance to HST Alternatives (mi) ^a	Fault Type	Estimated Mapped Length (mi) ^b	Most Recent Deformation ^c	Slip Rate (in per yr) ^d
<p>Notes:</p> <p>mi = miles</p> <p>ka = thousand years ago</p> <p>Ma = million years ago</p> <p>NI=No information. Detailed information was not available in the USGS and CGS databases (2009 and 2010).</p> <p>^a Distance to project alternative is the nearest distance of the fault to the nearest alternative.</p> <p>^b Mapped lengths are estimated based on the USGS and CGS mapping websites (2009 and 2010).</p> <p>^c If multiple years are shown for a given fault or fault zone, then there were multiple strands within the 65-mile radius with different years of "most recent deformation".</p> <p>^d Slip rate refers to horizontal slip rate.</p> <p>Sources: CGS (2009); USGS and CGS (2009 and 2010).</p>						

3.8.3 Surface Fault Rupture

Surface rupture can either occur suddenly during an earthquake or slowly in the form of fault creep. The amount of displacement during fault rupture can range from a few inches to many feet of permanent ground offset, and the sense of movement during fault rupture can be primarily horizontal, vertical, or some combination of the two, depending on the type of fault movement involved. Fault movement that includes a vertical component can result in regional ground subsidence in the area of displacement.

No active or potentially active faults or fault zones intersect (either directly or if the fault alignment is projected), or are adjacent to, the HST alternatives, including the north-south alignments, wyes, stations, and HMFs, as shown on Figure 3-10. The nearest active or potentially active faults would not result in horizontal ground movement or are located too distant to lead to appreciable ground subsidence; therefore there does not appear to be any risk of fault rupture, based on the information available from USGS and CGS.

3.8.4 Ground Shaking

Ground shaking occurs in response to energy released during a fault rupture. The energy travels through subsurface rock, sediment, and soil materials, resulting in motion experienced at the ground surface. Ground shaking intensity varies with the magnitude of the earthquake, the distance from the source of energy release, and the type of rock or sediment through which the seismic waves move. Depending on the level of ground motion and the stiffness of the soil, the ground motions can amplify or de-amplify.

The level of ground shaking along the proposed alternatives and HMF sites, was estimated following procedures in the 2007 CBC and the 2009 IBC. Results of this evaluation indicate that the most likely source of ground motions in the study area would be from smaller earthquakes (magnitude less than 7.0) originating at distances of less than 30 miles from the study area (USGS 2009). Large, distant earthquakes (magnitude greater than 7.0 at a distance greater than 60 miles) could also result in a significant contribution to the seismic hazard.

The levels of ground motion in the study area are moderate, with peak, firm-ground accelerations for a maximum considered earthquake ranging from 0.19g to 0.23g, where g is the acceleration due to gravity. This ground motion has a probability of exceedance of 2% in 50 years (USGS 2009). The return period associated with this probability of exceedance is approximately 2,475 years. Figure 3-11 shows expected relative intensity of ground shaking for the general area based on a probability of exceedance of 2% in 50 years. The ground motions in Figure 3-11 account for all potential seismic sources in the regional study area, the historic earthquakes that have occurred, slip rates on major faults, and the potential for amplification of surface waves by near-surface geologic materials.

The USGS peak, firm-ground acceleration estimates are based on modeling for a soft-rock geologic unit, referred to as Site Class B in the CBC and IBC. Because of the significant thicknesses of soft soils along the HST north-south alignments and the HMF sites, ground motions at the ground surface could approach or exceed 0.35g as a result of soil amplification effects, based on methods described by CGS and USGS to account for amplification and de-amplification. This level of ground shaking is sufficient to cause liquefaction of loose, saturated cohesionless soil, and will warrant special consideration during structural design. However, relative to the seismicity in areas such as San Francisco and Los Angeles, the estimated levels of ground shaking are significantly lower. Therefore, the risk of ground shaking within the HST System is considered moderate.

3.9 Secondary Seismic Hazards

A number of secondary seismic hazards could occur along the HST alternatives, including the north-south alignments, wyes, stations, and HMFs, if there is strong ground shaking at the site. The strong ground shaking could result from either nearby or distant earthquakes, depending on the combination of earthquake magnitude and distance from the project. These secondary hazards include liquefaction, seismically induced slides or slumps, and floods resulting from seismically induced dam failure. The following subsections discuss these hazards and identify possible locations of these hazards.

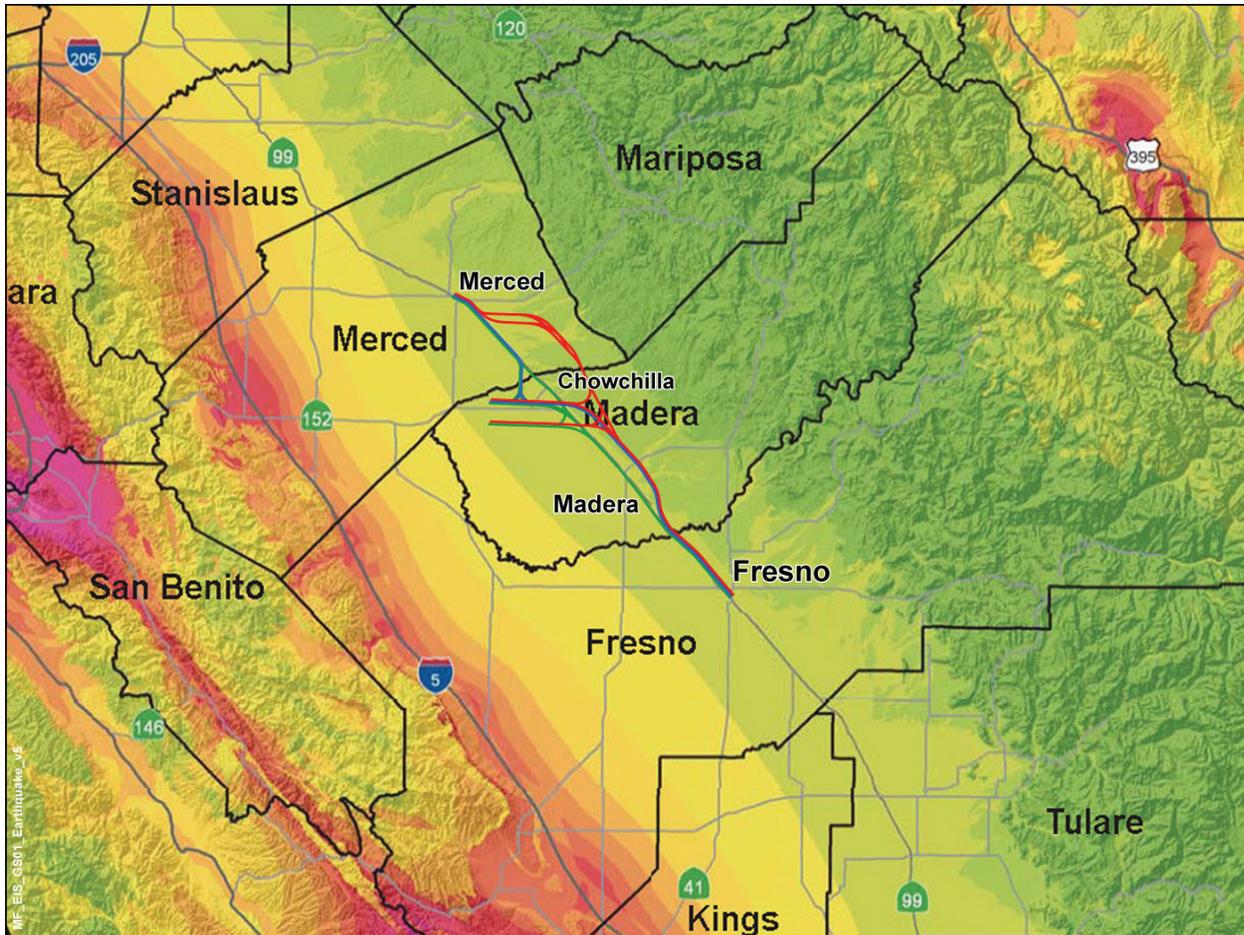
3.9.1 Liquefaction and Other Types of Ground Failure

Secondary seismic hazards include liquefaction and liquefaction-related ground failure such as localized settlement, lateral spreading, or flotation of buried vaults and pipes.

3.9.1.1 Liquefaction

The areas most prone to liquefaction have shallow groundwater (e.g., where the water table is less than 30 feet bgs) and consist of relatively loose to medium-dense sand. Soft cohesive soils (e.g., clay, some silts, and organic or peaty deposits) may also experience strength reduction during an earthquake, leading to ground failure. In addition to these soil and groundwater conditions, the ground acceleration and duration of the earthquake must be sufficient to induce liquefaction or ground failure. Madera County (1995b) and Fresno County (2000c) report that scientific studies have shown that the ground acceleration must approach 0.3g before liquefaction occurs in a sandy soil with relative densities typical to the San Joaquin alluvial deposits.

The cities and counties in the study area have not prepared specific liquefaction hazard assessments, and liquefaction hazard areas have not been mapped by the state. There also does not appear to be a consistent view on liquefaction by the cities and counties. Although groundwater is anticipated to be shallower than 30 feet bgs in some areas, Madera County (1995b) and Fresno County (2000c) suggest that soil types in the area are generally not conducive to liquefaction because they are either too coarse or too high in clay content. However, Merced County (2007) assumes that liquefaction hazards exist in wetland areas. The cities of Atwater, Chowchilla, Merced, Madera, and Fresno recognize that liquefaction hazards exist adjacent to waterways or in areas of unconsolidated sediments and a high groundwater table (City of Atwater 2000, City of Chowchilla 2009, City of Merced 1997, City of Madera 2009b, City of Fresno 2002).

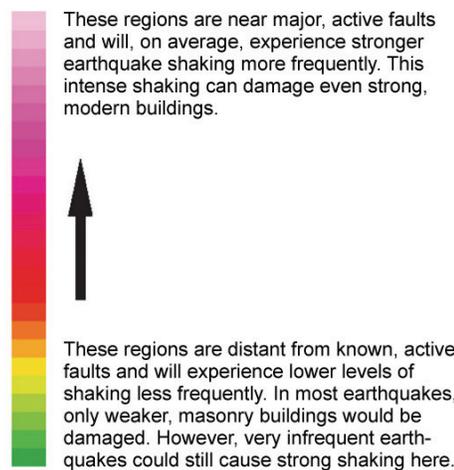


Source: Branum, D., S. Harmsen, E. Kalkan, M. Petersen, and C. Wills (2008) Earthquake Shaking Potential for California. CGS and USGS Map Sheet 48.

December 3, 2010

- UPRR/SR 99 Alternative
- BNSF Alternative
- Hybrid Alternative
- County Boundary

Level of Earthquake Hazard



Shaking Potential

The shaking potential is calculated as the level of ground motion that has a 2% chance of being exceeded in 50 years, which is the same as the level of ground-shaking with about a 2,500-year average repeat time.

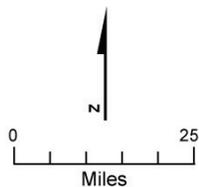


Figure 3-11
 Expected Relative Intensity of Ground Shaking in the Project Vicinity

As suggested by the cities, the soils beneath and adjacent to natural waterways crossings would be the primary locations susceptible to liquefaction hazards. At these locations the potential for liquefaction exists if saturated, near-surface soils are loose and cohesionless. Available exploration data indicate that such soils occur on a localized basis, particularly at river and stream crossings. Based on the shallow location of water principally at the waterway crossings and the potential occurrence of loose, cohesionless soils, the liquefaction potential for the HST alternatives and HMF sites is interpreted as follows:

- **North-South Alignments:** There are over 20 natural waterway (river or stream) crossings for each alternative, and these would be candidate locations for liquefaction.
- **Stations:** Neither the Merced Station nor the Fresno Station involve waterways, and therefore, are not likely locations of liquefaction.
- **HMFs:** There are two natural waterway crossings at the Castle Commerce Center and Gordon-Shaw HMF sites, one each at the Harris-DeJager and Kojima Development HMF sites. These would be candidate locations for liquefaction. There are no natural waterway crossings at the Fagundes HMF site.

Other locations that would be susceptible to liquefaction are the random areas of shallow groundwater that could occur between the waterways. Detailed explorations during subsequent phases of design will be required to evaluate whether shallow groundwater occurs and whether the combinations of groundwater conditions, soil type, and soil density could result in liquefaction during design seismic loading.

Because of the multiple locations of potential liquefaction hazards and the potential consequences of liquefaction, as discussed in the next section, there is a moderate risk of liquefaction within the HST alternatives.

3.9.1.2 Other Types of Ground Failure

Several types of ground failure could occur in areas of liquefaction, including loss of vertical and lateral bearing support of a foundation resting on or supported in liquefied soils, lateral spreading or lateral flow next to rivers and similar topography, and post-earthquake settlement of liquefied soils as pore-water pressure formed during earthquake shaking dissipates.

These types of ground failure are more common in locations where liquefaction occurs close to the ground surface, either beneath or adjacent to waterways. The waterway crossings discussed in Section 3.9.1.1 are potential locations of ground failure associated with liquefaction.

3.9.2 Seismically Induced Landslide Hazards

Earthquake ground shaking can induce landslides where slopes are prone to failure because of geologic conditions or human modification. A review of topographic, landslide inventory, and landslide hazard maps prepared by USGS and CGS found generally flat topography for the project vicinity, except along localized rivers and creek banks, and no existing landslides within and adjacent to the HST alternatives, including the north-south alignments, wyes, stations, and HMFs.

Seismically induced surficial slides or slumps could occur along river or creek banks where the inertial effects of ground shaking in combination with gravity loads exceed the strength of the soil. When this exceedance occurs, slope movements can result and, depending on magnitude of movement, failure can ensue. This hazard is most critical where slopes are steep, e.g., greater than 2H:1V, and where soil strength is low; e.g., factor of safety under static loading less than about 1.5. All of the natural waterway crossings in the project study area are candidate locations for these types of failures. The consequences of landslides or slumps on the HST System during operation would be significant, and therefore careful evaluation of these waterway crossings will be required during final design.

3.9.3 Seismically Induced Flood Hazards

A number of dams are located east of the HST alternatives and HMF sites. If any one of these dams were to fail during a seismic event, the consequence could be flooding within the study area. Either earthquake ground shaking or fault rupture, which would result in ground offsets beneath the dam, could be the cause of the dam failure, or seiches induced by the ground shaking might damage the structures. Because of the potential hazard from dam breaks, the State of California and the counties have prepared dam inundation maps to identify the risk to the public should a dam fail.

Potential dam failure inundation areas, as mapped by the counties, are shown in Figure 3-12 (Merced County 2007, Madera County 1995b, Fresno County 2000b). A review of these dam failure inundation maps shows that nine dams or reservoirs are potential sources of water inundation of the study area from dam failure—Lake Yosemite, Bear Reservoir, Owens Reservoir, Mariposa Reservoir, Buchanan Dam at Eastman Lake, Hidden Dam at Hensley Lake, Friant Dam at Millerton Lake, Big Dry Creek Dam at Big Dry Creek Reservoir, and Pine Flat Dam at Pine Flat Lake. The areas of water inundation resulting from failure of one of these dams intersect the HST alignment at the cities of Atwater, Merced, Planada, Le Grand, Chowchilla, Madera, Herndon, and Fresno. The inundation areas shown represent conservative scenarios based on two key assumptions:

- Seismic shaking associated with the seismic event causes catastrophic failure of the dam/retaining structures, and
- Retained waters are at their maximum operating elevation (not the maximum flood stage) at the time of the seismic event.

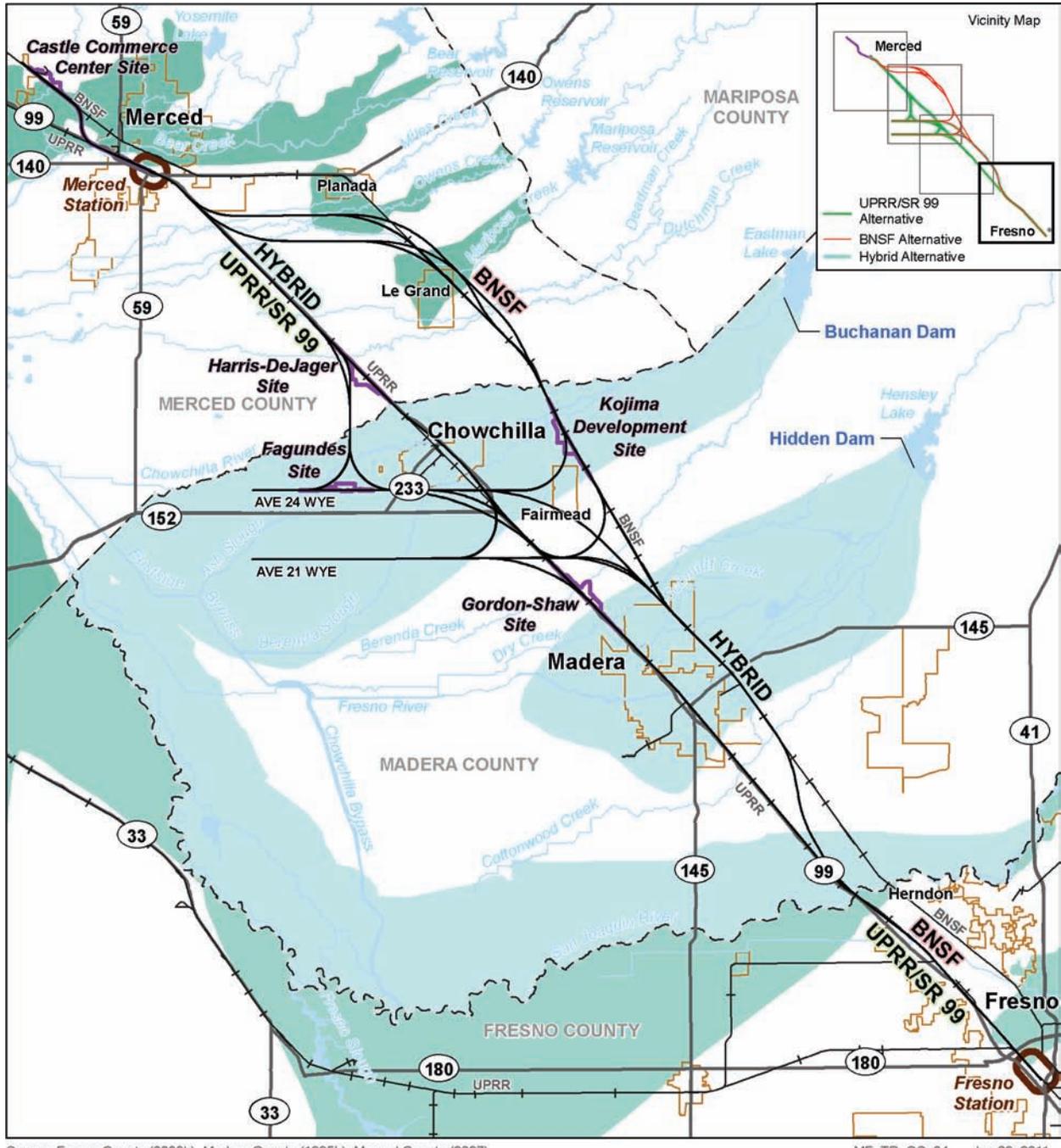
Based on these conditions, water inundation depths could overtop the banks of the San Joaquin River (Madera County, Fresno County, and the City of Fresno 1986), and result in water being over the top of the rail tracks in some areas. Neither the State Office of Emergency Services nor the Department of Water Resources formulates a probability factor for dam failure, nor have the counties undertaken comprehensive studies of the potential for dam failure.

The Department of Water Resources' Division of Safety of Dams annually inspects each dam to ensure the dam is safe, performing as intended, and not developing problems. The Division of Safety of Dams also periodically reviews the stability of dams and their major appurtenances in light of improved design approaches and requirements, as well as new findings regarding earthquake hazards and hydrologic estimates in California. Based on the level of inspection by various state and federal agencies, as well as the overall awareness of the potential consequences of a dam failure for the area, the risk of dam failure is believed to be very low. This low risk suggests that inundation from dam failure should also be considered very low along the HST alternatives.

3.10 Areas of Difficult Excavation

Subsurface geologic conditions affect the ease or difficulty of excavation, which in turn determines the appropriate excavation techniques during construction. In most cases, difficult excavation is associated with the occurrence of shallow bedrock. Bedrock in the study area is expected to be 6 miles deep; therefore, there is no risk of difficult excavation because of bedrock. For these discussions difficult excavation is defined as excavation methods requiring more than standard earth-moving equipment or special controls to enable to work to proceed.

The types of soils (alluvial, lake, and floodplain) expected within areas requiring excavation typically are not difficult to excavate. However, cemented zones and hardpan can occur within the study area, particularly along the BNSF alignment; the cemented zones and hardpan can be rock-like in consistency. These cemented zones and hardpan form as a result of the soil weathering process and can develop in most of the surficial site soils previously described. These cemented zones and hardpan may pose local excavation issues for conventional machinery, depending on the thickness and degree of



Source: Fresno County (2000b), Madera County (1995b), Merced County (2007).

MF_TR_GS_04 Jun 29, 2011



Figure 3-12
 Potential Dam Failure Inundation Areas
 in the Project Vicinity

cementation of the hardpan or cemented layer. In areas that have been used for agricultural purposes, the hardpan has often been removed or tilled to improve the drainage characteristics of the soil. Past land use, as well as infrastructure development in the study area, should limit the locations where hardpan and cemented zones pose a potential problem for excavations.

Another factor that may make some types of excavations difficult is the combination of soil conditions and shallow groundwater that could be encountered when excavating below-grade sections of track. Any time excavations extend below groundwater levels there is a need to prevent excess hydrostatic pressures. These conditions are most critical where loose, cohesionless deposits have to be excavated in areas of high groundwater, such as has been noted for the river crossings areas. Conditions between Atwater and Merced could also have high groundwater and localized, near-surface deposits of loose cohesionless soils that could create difficult excavation. Refer to Section 3.5.2, Subsurface Geotechnical Conditions, for a summary of groundwater depths in the study area.

3.11 Mineral and Energy Resources

The assessment of geology, soils, and seismicity included a review of mineral and energy resources. Energy resources include fossil fuel (oil and gas) resources and geothermal resources. The main issue associated with energy resources would be the loss of access to a resource caused by the placement of high-speed rail facilities. Additionally, the presence of certain energy resources, such as subsurface oil and gas deposits or geothermal resources, could affect the construction and operation of the proposed project.

3.11.1 Mineral Resources

Active mining operations in the region are for building materials or aggregate (sand and gravel) and industrial minerals (e.g., lime, pumice, and gypsum). Results of the geologic resource review found that aggregate resources are the only mineral resources within the study area, specific to mineral and energy resources, as defined in Section 3.3.

The occurrence of aggregate resources was defined in terms of mineral resource zones (MRZs). The State of California uses MRZs to identify areas where significant mineral deposits of Portland cement concrete-grade aggregate (valued for its versatility and its importance in construction) are present (MRZ-2) or absent (MRZ-1). Results of the review of mineral resources indicated the following:

- The study area is classified as MRZ-1. The nearest MRZ-2 is along the San Joaquin River between the Friant dam and SR 99 (City of Fresno 2002), about 1 mile from the UPRR/SR 99, BNSF, and Hybrid alternatives.
- Locally important mineral resource recovery sites are not located within the study area.
- Aggregate production areas and the amount produced within those areas are shown in Figure 3-13. Generally, the 50-year demand for aggregate exceeds the permitted resource.

Table 3-12 provides values for the 50-year demand versus the permitted aggregate resources for the Fresno production-consumption (P-C) Region and Merced County and projects that the Fresno P-C Region has less than 10 years of permitted aggregate resources remaining.

Table 3-12
 Comparison of 50-year Demand to Permitted Aggregate Resources for Aggregate Study Areas as of January 1, 2006

Aggregate Study Area ^a	50-Year Demand (million tons)	Permitted Aggregate Resources (million tons)	Permitted Aggregate Resources as Percentage of the 50-Year Demand
Fresno P-C region ^b	629	71	11%
Merced County ^c			
Eastern Merced County	106	53	50%
Western Merced County	53	Proprietary	<50%

^a Aggregate study areas follow either a P-C region boundary or a county boundary. A P-C region includes one or more aggregate production districts and the market area that those districts serve. Aggregate resources are evaluated within the boundaries of the P-C region. County studies evaluate all aggregate resources within the county boundary.

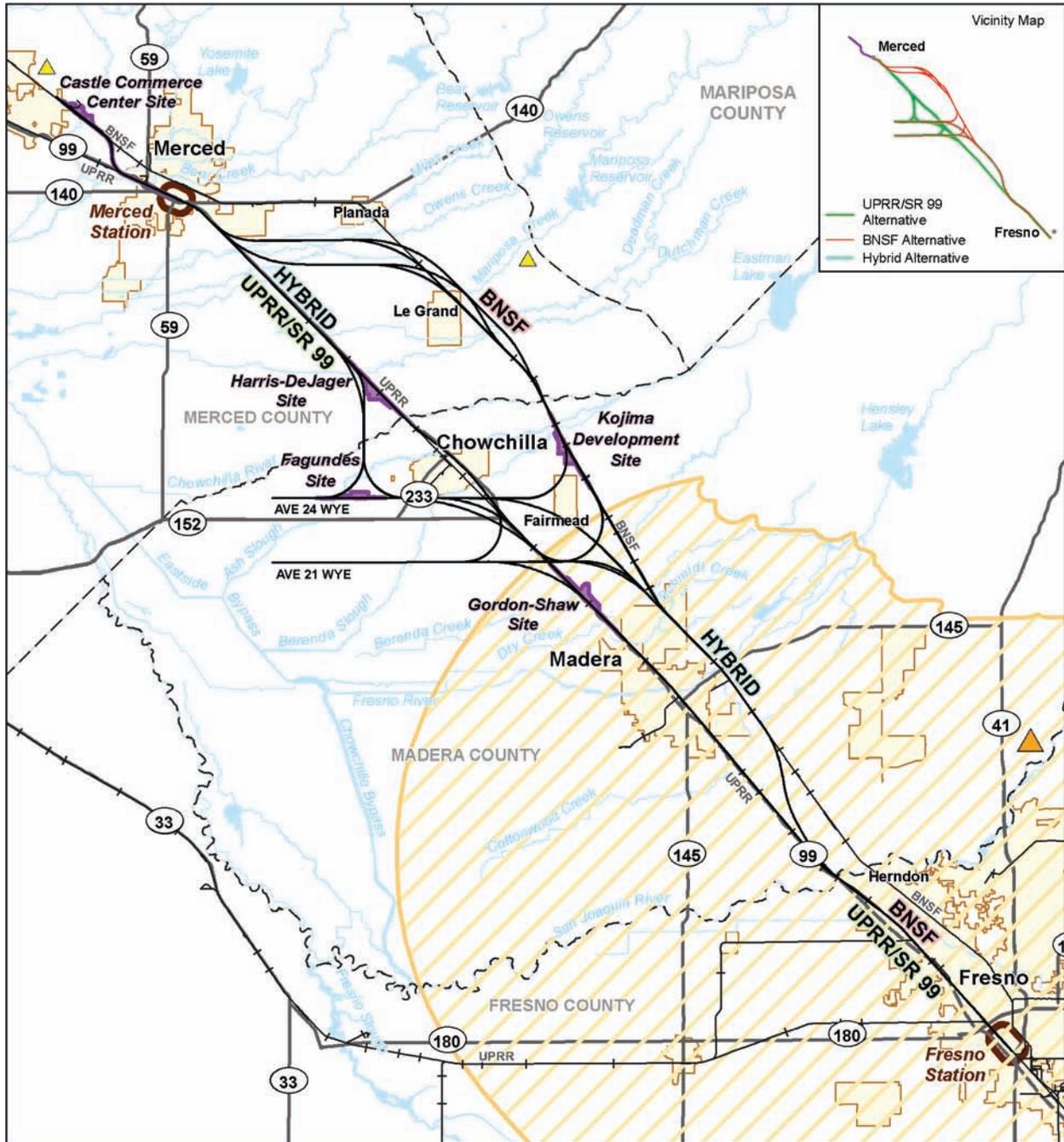
^b The Fresno P-C region has less than 10 years of permitted resources. This estimate was calculated by comparing the currently permitted resources to the projected annual aggregate consumption in the study area on a year-by-year basis. This is not the same as dividing the total projected 50-year demand for aggregate by 50 because, as population increases, so does the projected annual consumption of aggregate for a study area.

^c The Merced County aggregate study has been divided into two areas, each having its own production and market area. A separate permitted resource calculation and 50-year forecast is made for each area. Tonnages are not given for eastern Merced County to preserve company proprietary data.

Source: Kohler (2006).

3.11.2 Fossil Fuels and Other Energy Resources

The online mapping system of the California Department of Conservation DOGGR website (Department of Conservation 2009) identifies a total of 16 oil or gas wells located within the study area along the HST north-south alignments, wyes, stations, and HMF sites. These wells were exploratory or stratigraphic for geologic purposes only, and are now inactive and have been plugged and abandoned. The locations of these plugged and abandoned wells are shown in Figure 3-14. No oil or gas fields were identified (DOGGR 2001), nor are there any geothermal resources (fields, wells, or springs) along the HST alternatives (DOGGR 2002).



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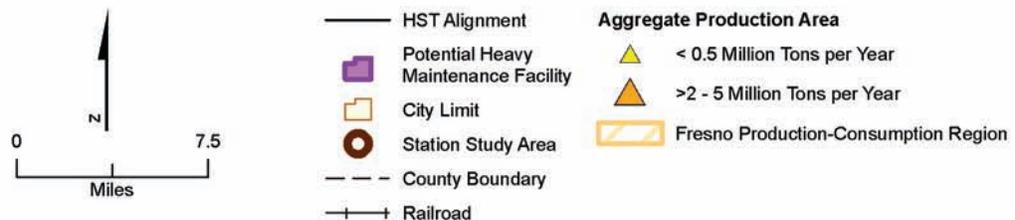
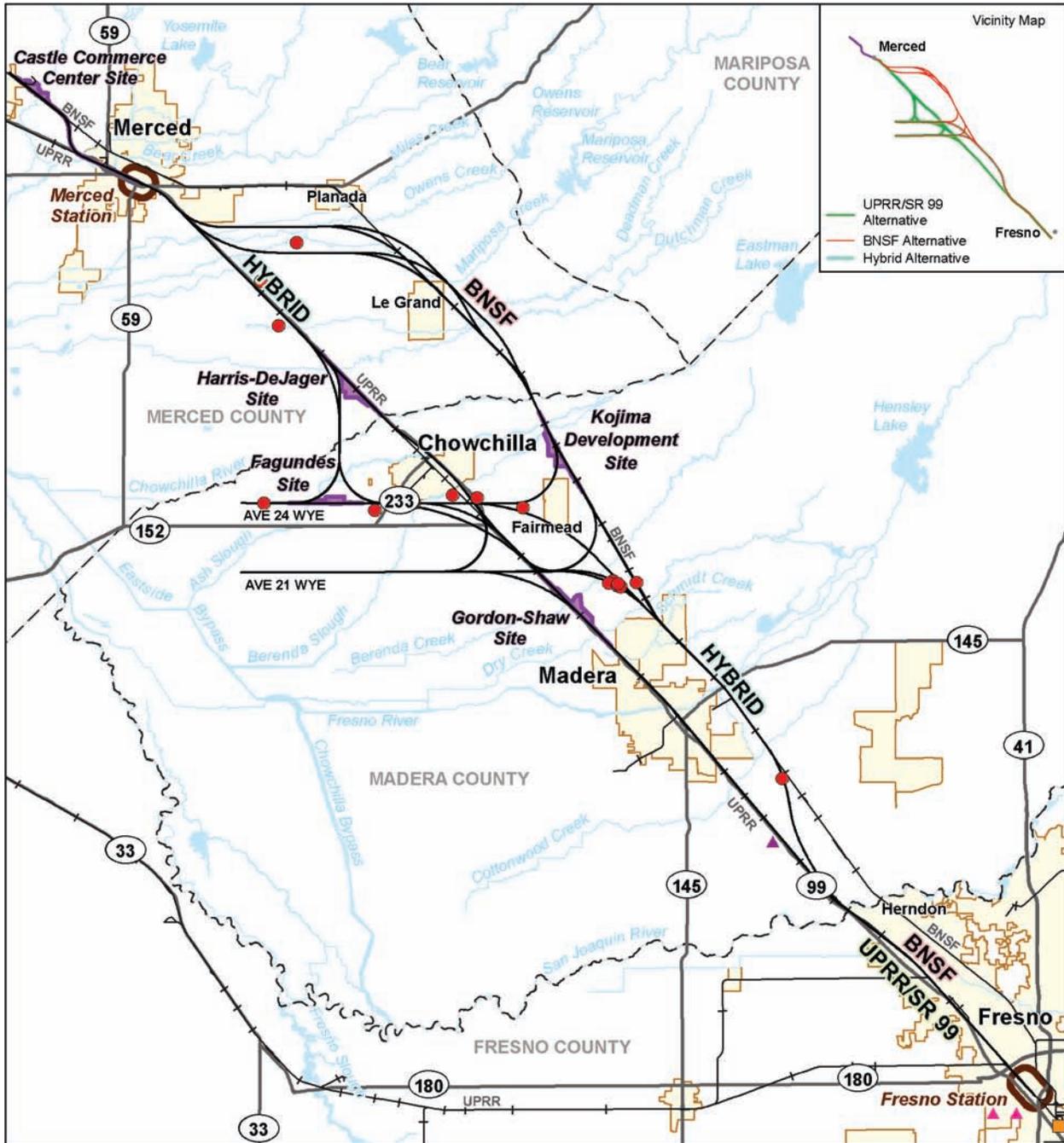
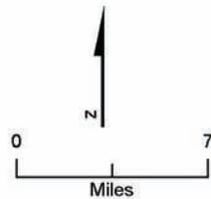


Figure 3-13
 Aggregate Production Areas
 in the Project Vicinity



MF_TR_GS_05 Jun 29, 2011



- HST Alignment
- Potential Heavy Maintenance Facility
- City Limit
- Station Study Area
- - - County Boundary
- + + Railroad
- Oil or Gas Well Status
 - Plugged and Abandoned Dry Holes
- Mineral Resource: Commodity, Status
 - Gold, Unknown
 - ▲ Sand and Gravel, Construction, Past Producer
 - ▲ Sand and Gravel, Construction, Producer

Figure 3-14
 Mineral Resources and Oil, Gas, and Geothermal Wells in the Study Area

4.0 Environmental Consequences

This section describes the impact analysis related to geology, soils, and seismicity for the proposed project. The description includes

- An overview of the methodology used to evaluate environmental consequences,
- A summary of environmental consequences associated with the No Project Alternative, and
- A discussion of environmental consequences resulting from the construction and operation of the HST System.

The environmental consequences of construction and operations for the HST System are identified in this section as if normal design and construction measures were not used. However, in order to meet normal standards of engineering design, the consequences of construction and operation must be addressed in such a way that once constructed, the risk from the consequence has been either eliminated or reduced to a level that adequately protects the public. By following these standards, the risk of an unacceptable consequence should not occur. If this design process is not followed, then the engineers or scientists responsible for design have not carried out their responsibilities to protect the public and to prevent damage to the environment. Measures that will be implemented as part of standard design to address potential risks from geology, soils, and seismicity are described in Section 5.

4.1 Methodology

Impacts related to geology, soils, and seismicity were analyzed qualitatively, based on a review of published soils and geologic information for the proposed HST alternatives, including the north-south alignments, wyes, stations, and HMFs. The analysis focused on the proposed project's potential to increase the risk of personal injury, loss of life, and damage to property, including new facilities, as a result of existing geology, soils, and seismic conditions in the study area and the potential adverse effects of the project on the existing geology, soils, and seismicity (e.g., erosion of topsoil). The following three subsections summarize the approach used to compare the HST alternatives and the HMF sites, the method used to classify risk relative to NEPA and CEQA descriptions, and engineering work that will occur during future phases of design.

4.1.1 Comparison of Alternatives and HMFs

As discussed in the Section 3 introduction, the affected environment for the north-south alignments, wyes, stations, and HMF sites is generally very similar within the Merced to Fresno Section. This similarity results from the geological processes forming the surface and subsurface soils that make up the Central Valley of California. These geologic processes have led to a very flat topography, competent soils in most areas, and deep groundwater along the alternative alignments. The similarity in origin and conditions also makes it difficult to quantitatively compare one alternative to another or one HMF to another relative to geology, soils, and seismicity. There is not sufficient information nor are the differences great enough to warrant a detailed comparison at this point in project development, and it is very unlikely that the differences in geology, soils, and seismicity between the alternatives will play a role in alignment or HMF site selection. For this reason the following discussion of environmental consequences considers the consequences in general for construction period and project (operational) impacts.

Geologic, soil, and seismic conditions are similar for all HST alternatives and risks can be addressed with the conventional foundation design methods used to reduce geologic risks where they are present. These foundation design methods are available for elevated structure, retained fill, at-grade, and retained cut components of each alignment. The engineering design methods are included in AASHTO, AREMA, Caltrans, and IBC standards and guidelines, as described in Section 3.3.4, Design Standards and Guidelines.

Although the overall severity of geologic conditions and hazards is relatively similar for the HST alternatives, as design work for the HST progresses, site-specific explorations will be carried for each alternative and for the HMFs. The results of these explorations will likely show that soil and groundwater conditions vary from location to location, and these variations could warrant special design requirements, such as the use of deep foundations for building or elevated structure support and the use of ground improvement to mitigate seismic hazards. Regardless of the location-by-location differences; the geology, soils, and seismicity appear to be such that standard design methods and construction measures can be used to successfully address the risk of geologic impacts.

4.1.2 Classification of Geologic Risks

There are a limited number of geologic risks that will have to be considered during design and construction. For example, unstable soils and settlement would present a moderate risk to existing infrastructure or new HST facilities if they were not appropriately considered during design. However, with incorporation of standard engineering design features during construction of the HST, unstable soils and settlement would present a low risk to existing infrastructure, including existing roadways, bridges, buildings, and residential structures, or new HST facilities, such as elevated, retained fill, at-grade, and retained cut segments of the alignments.

The severity of these risks is limited because the geology along the HST alternatives and HMF sites is generally very competent, with only localized areas of potentially soft or loose soils that could be subject to bearing capacity issues or excessive settlement. Where geologic hazards exist, well-proven methods outlined in standard guidance and engineering standards exist to address these hazards. For example, during construction, stockpiles of topsoil could erode due to wind and water if BMPs are not followed. By implementing provisions in the *Construction Site Best Management Practice (BMP) Field Manual and Troubleshooting Guide* (Caltrans 2003a), wind and water erosion would be addressed.

Likewise, in the absence of appropriate implementation of design standards and guidelines, a number of potential operational impacts exist for HST alternatives. These impacts potentially include low soil bearing strength, soil settlement, shrink-swell and corrosive soils, slope failures, ground shaking, and secondary seismic hazards such as liquefaction, liquefaction-related slope movement, and liquefaction-related settlement. These impacts range from moderate to substantial, and would be considered significant according to CEQA requirements because each could cause loss of life or significant environmental impacts, if appropriate HST track designs were not incorporated. However, the project will be required to comply with appropriate building codes and design standards in AASHTO, AREMA, Caltrans, and IBC, as described in Section 3.3.4, Design Standards and Guidelines. These codes and standards require that the design consider and address engineering solutions for the performance of the soils, including potential for settlement, bearing capacity of soils, slope instability, and seismic loadings during final design. The use of Caltrans' design criteria will also meet the requirements for seismic and foundation design, and the application of the Caltrans Construction Site Field Manual and Troubleshooting Guide (Caltrans 2003a) will address wind and surface water erosion.

With proper incorporation of these guidelines, the severity of these impacts on elevated, retained fill, at-grade, and retained cut segments of the alignments would be limited.

4.1.2.1 Methods for Evaluating Effects under NEPA

Pursuant to NEPA regulations (40 CFR 1500-1508), project effects are evaluated based on the criteria of context and intensity. Context means the affected environment in which a proposed project occurs. Intensity refers to the severity of the effect, which is examined in terms of the type, quality, and sensitivity of the resource involved, location and extent of the effect, duration of the effect (short- or long-term), and other consideration of context. Beneficial effects are identified and described. When there is no measurable effect, impact is found not to occur. Intensity of adverse effects is summarized as the degree or magnitude of a potential adverse effect where the adverse effect is thus determined to be negligible, moderate, or substantial. It is possible that a significant adverse effect may still exist when on

balance the impact is negligible or even beneficial. For geology, soils, and seismicity, the terms are defined as follows:

A *negligible* impact is defined as an increased risk or adverse effects related to geology, soils, and seismicity that are slightly greater, but very close to the existing conditions. A *moderate* impact is defined as an increased risk of personal injury, loss of life, and damage to property as a result of existing geologic, soils, and seismic conditions and adverse effects of the project on the existing geology, soils, and seismicity in specific sites or localized areas but that would not have wide-ranging effects. *Substantial* effects are defined as increased risk of personal injury, loss of life, and damage to property as a result of the project on a regional scale. Additionally, adverse effects of the project on the existing geology, soils, and seismicity (e.g., erosion of topsoil) on a regional scale are substantial effects.

4.1.2.2 CEQA Significance Criteria

Based on the CEQA Guidelines, including Appendix G, a project would result in a significant impact if it would:

- Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving the following:
 - 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.
 - Strong seismic ground shaking.
 - Seismically related ground failure, including but not limited to, liquefaction.
 - Seiche or tsunami hazard.
 - Dam failure inundation hazard.
 - Landslides, including seismically induced landslides.
- Result in substantial soil erosion or the loss of topsoil.
- Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, with the potential to result in onsite or offsite landslide, lateral spreading, subsidence, liquefaction, or collapse.
- Be located on expansive soil, as defined in Table 18-1-B of the current UBC, creating substantial risks to life or property.
- Be constructed on corrosive soils, creating substantial risks to life or property.
- Result in the loss of availability of a known mineral, petroleum, or natural gas resource of regional or statewide value.
- Result in the loss of availability of a locally important mineral resource recovery site.
- Be located in an area of subsurface gas hazard, creating substantial risks to life or property.

4.1.3 Engineering Considerations for Future Design

Federal and state guidelines and regulations have engineering requirements for avoiding the potential risks present in the Merced to Fresno Section. The next phase of engineering will design for the following:

- Unstable soils due to local deposits of soft cohesive soils or loose cohesionless soils. These soils would most likely be found at rivers and streams; however, they could occur at other locations along

HST and HMF alternatives. This potential impact occurs during construction and operation and is addressed during the design phase.

- Compressible soils due to local deposits of soft cohesive soils and loose cohesionless soils. These soils would most likely be found at rivers and streams; however, they could occur at other locations along each HST alternative and HMF site. This potential impact occurs during construction and operation.
- Surface soils that could be eroded by the forces of wind and water. Soils along the HST and HMF alternatives generally exhibit moderate to high water and wind erosion potential. This potential would be highest where vegetated soils are exposed during construction or operation, and where wind velocities or water runoff velocities are high. This potential impact occurs during construction and operation. It represents a potential for erosion and loss of topsoil; however, normal BMPs can be used to avoid this occurrence.
- Soils that have moderate to high shrink-swell potential and corrosivity characteristics. These soils are found at most locations along the HST and HMF alternatives. This potential impact occurs mainly during operation and can be addressed through the selection of appropriate design details to prevent a change in moisture content or by removing and replacing areas where the potential impact is unacceptable with materials that are not prone to shrink-swell, or by mixing additives with existing soils.
- Slope failures along streams and embankments. Most of the area along the HST and HMF alternatives is very flat, and most slopes where they do occur are less than 10 feet in height. However, the consequences of slope failure could be serious for the HST, even when slopes are 10 feet or less in height; therefore, this impact would be considered along streams and planned embankments. This potential impact occurs during construction or operation. The potential for slope instability is a routine part of geotechnical design; a number of methods can be used to mitigate this potential as summarized in the next section.
- Seismic ground shaking at all locations. The levels of shaking could be moderate, representing a risk to structures and to the soils supporting structures. Therefore, the impacts from ground shaking need to be addressed. This risk occurs mainly during operation. Once the risk is identified during design, the structure or the soil can be strengthened to handle the levels of ground shaking without excessive nonlinearity in the structure or the ground.
- Secondary effects of seismic shaking. These include slope instability, liquefaction, and liquefaction-induced slope movement or settlement. Though the number of locations susceptible to these effects is limited, the consequences would be high if they were to occur and, therefore, impacts of these hazards would also be considered. These risks occur primarily during operation. They are routinely evaluated during design, and where necessary, the hazard can be avoided by implementing well-proven design methods.

4.2 No Project Alternative

The population in the San Joaquin Valley has been and is projected to continue growing (Council of Fresno County Governments 2007). To accommodate this growth, farmland has been and will continue to be converted to other uses, such as residential developments, small business, light industrial development, and transportation infrastructure. Foreseeable future projects, which include shopping centers, large residential developments, quarries, and, of particular note, expansion of SR 99 to include full access interchanges and additional auxiliary lanes, are slated for completion by 2020 between Merced and Fresno. These projects are planned or approved to accommodate the growth projections in the area.

Local, county, state, and federal jurisdiction plans and policies require consideration of the risks of development on public safety and on the potential for property damage caused by geology, soils, and seismicity, as well as the effects of development on geology, soils, and seismicity. The primary risks to development are the same as those identified in Section 4.1.2. These risks include localized deposits of

soils that have low bearing support or exhibit excessive settlement under load, or involve geologic hazards from steep slopes near rivers and streams, primary seismic hazards from earthquake ground shaking, and secondary hazards from earthquake-induced liquefaction and slope failures. The risks to geology, soils, and seismicity from development would be primarily associated with changes in local conditions that result in greater water or wind erosion, loss of valuable topsoil, or constraints on the potential for oil and gas resource development. Some elements of geology, soils, and seismicity would not be affected, whether development occurs or does not occur. Examples of these would be the overall geologic setting, the general topography, and the potential for earthquake ground shaking.

Applicable city, county, state, and federal regulations would be followed during development. These regulations either avoid or limit the extent of adverse impacts. The regulations include the IBC and the CBC. By following these regulatory requirements, the health and safety of the public, as well as the value of property, would be protected to the extent practical under the No Project Alternative.

Even when complying with various jurisdictional regulations and building code requirements, individual project impacts by themselves may be small, but, when combined with the overall development of the area, would represent important cumulative impacts resulting from or to geology, soils, and seismicity. The increasing population density will result in development in areas where the risk of geologic and seismic hazards, such as slope instability near rivers or liquefaction in areas of liquefiable soils, is higher, ultimately resulting in more risk to the public and a greater chance of property damage. In addition, the use of older buildings to accommodate the increasing population density would present a risk during a seismic event, as these buildings were typically built to less stringent standards.

4.3 High-Speed Train Alternatives

This section summarizes the environmental consequences for the HST alternatives in three sections. The first section summarizes the environmental consequences that have been reviewed and conclusions have been made that they do not represent risks of impact. The non-risk conclusions will be considered in greater detail again during design but further evaluation is expected to confirm that these potential consequences are non-risks. The last two sections summarize the construction-period impacts and the project (operational) impacts. These impacts will be considered during design and construction, and where they are found to represent a hazard based on normal design standards, guidelines, or code requirements, design or construction methods would be selected to avoid the risk.

4.3.1 Common Non-Risks Occurrences

The following geology, soils, and seismicity occurrences are not a risk (i.e., non-risk) because the conditions are unlikely to occur, they are located too distant from the project to represent a meaningful risk, or the cause of the risk no longer exists:

- Landslides. The topography is flat and there is no evidence of landslides that encompass large areas. Slumps and similar lesser forms of slope failures are possible on a localized basis at stream and river crossings.
- Land subsidence from water, oil, gas, or geothermal wells. Water withdrawal is controlled during construction to minimize the potential for localized ground subsidence. There are no known active oil, gas, or geothermal wells near the project that could result in regional ground subsidence.
- Ash fall from a volcanic eruption within the Mono Lake-Long Valley Volcanic Area. Volcanic activity in the Mono Lake-Long Valley Volcanic Area is very low according to the USGS (e.g., 1% per year), and the prevailing wind is away from the project site, making the chance of ash fall negligible.
- Fault Rupture. Ground movement from fault rupture was not considered because the closest active or potentially active fault was located at least 25 miles from the HST alternatives and HMF sites.

- Seiches and tsunami flooding. There are no oceans, bays, or other bodies of water sufficient to result in a damaging seiche or tsunami near the project alignments.
- Difficult Excavation. The depth of rock is estimated to be 6 miles below the ground surface. Difficult excavation due to hardpan and shallow groundwater is discussed in Section 4.3.2, Construction Period Impacts.
- Disruption of mineral, fossil fuel, and geothermal resources. Active wells or fields do not exist in the project vicinity. If any unidentified wells were encountered during construction, these wells would be demolished or abandoned per city and county regulations.

4.3.2 Construction Period Impacts

Impacts during the construction period are associated with the equipment and materials used to perform the construction, as well as the direct and indirect impacts of the construction activities. Construction activities have the potential to cause a number of short-term impacts on the environment related to geology and soils. The potential impacts include localized deposits of low-strength soils that could lead to ground failure, areas with potential for ground settlement, soil erosion, and localized areas of difficult excavations due to hardpan and shallow groundwater. These potential impacts during construction are common to all HST and HMF alternatives. Each of the risks described below will be addressed during the course of engineering design.

4.3.2.1 Common Geology, Soils, and Seismicity Impacts

Unstable Soils Resulting in Onsite or Offsite Slumps and Small Slope Failures

Unstable soils consist of loose or soft deposits of sands, silts, and clays. These soils exhibit low shear strength and, when loaded, can fail through bearing failures or slope instabilities. Although the HST north-south alignments, wyes, stations, and HMFs appear to be sited predominantly along areas characterized as competent soils near the ground surface, unstable soils can occur on a localized basis, particularly near river and stream crossings. Stream crossings and proximity to streams are listed and discussed for each HST alternative and the HMF alternatives in the *California HST Merced to Fresno Section Draft Project EIR/EIS Hydrology and Floodplains Technical Report* (Authority and FRA 2011).

Construction of the project on soft or loose soils could result in onsite or offsite slumps and small slope failures at stream crossings, instability of cut-and-fill slopes required for the HST tracks, or collapse of retaining structures used for retained fills or retained cuts. Over 50% of exploration locations in the corridor have loose to medium dense soils close to the ground surface. Such soils would have relative densities of 20% to 60%, which would make them potentially susceptible to low static strength.

Locations that have either soft fine-grained soils or loose-to-medium dense granular soils and could exhibit risks of bearing failures and slope instabilities are as follows:

- UPRR/SR 99 Alternative: Franklin Road overcrossing, Bear Creek, East Merced overhead, Miles Creek, Duck Slough Bridge, Deadman Creek, Dutchman Creek, Chowchilla River, Dry Creek, Fresno River, West Fourth Street overcrossing, Avenue 11 overcrossing, Avenue 8 overcrossing, and the San Joaquin River.
- BNSF Alternative: BNSF railroad underpass at G Street, Bear Creek Bridge, and Campus Park overhead.
- Hybrid Alternative: Franklin Road overcrossing, Bear Creek, East Merced overhead, Miles Creek, Duck Slough Bridge, Deadman Creek, Dutchman Creek, and Chowchilla River.
- HMFs: The segment of the alignment between Atwater and the City of Merced could be more prone to unstable soils because of the high groundwater conditions relative to sections of the HST alignment to the south. There are two natural waterway crossings at the Castle Commerce Center

and Gordon-Shaw HMF sites. The other three HMF sites have no natural waterway crossings or only one waterway crossing.

Slumps and slope failures could endanger people or onsite or offsite properties. Although this risk would be greater if a large seismic event were to occur, the likelihood of a large earthquake during construction is considered low because of the relatively short duration of construction relative to the frequency of large earthquakes.

This type of impact is mostly associated with retained fill because the additional weight imposed on the ground can cause bearing capacity failures if the load exceeds the bearing strength of the soil. Conventional design methods are available to evaluate the potential for bearing failure, and where potential bearing capacity issues exist, various conventional construction methods are available to reduce the risk of these issues, including the use of ground improvement or the use of lightweight fills.

With implementation of normal design standards and guidelines in addition to standard safety practices during construction, these risks would be negligible under NEPA and less than significant under CEQA.

Soil Settlement at Structures or Along Trackway

Soil settlement could occur during project construction if imposed loads cause compression of the ability of the underlying materials. It is a time-dependent process and is most problematic at locations where soft deposits of silty or clay soils exist and have not previously been subjected to the levels of load caused by placing earth fill at the approach to and terminus of elevated structures, for retained fills segments of the alignment, or for adding ballast materials to meet track grade requirements during construction. Although soils along the alignments are generally competent (medium dense, stiff, or better), localized deposits of soft or loose soils could occur at various locations, particularly at water crossings where soft or loose soils appear to be more prevalent.

Soil settlement would be primarily a track design issue; however, in some locations, settlement could also affect nearby existing structures or buried utilities located close to the area of construction. This impact would result from either new earth fills, including retained fills, placed in areas that are underlain by settlement-prone (loose or soft) soils or from dewatering excavations for below-grade sections of track where shallow groundwater occurs and soils are loose or soft. Several borings at river and stream crossings along the HST alternatives had soil descriptions indicating soft or loose soils.

Geotechnical explorations prior to construction would identify locations with the potential for settlement. Locations that are known to have soft fine-grained soils or loose to medium dense granular soils and could exhibit risks of settlement are as follows:

- UPRR/SR 99 Alternative: Franklin Road overcrossing, Bear Creek, Chowchilla River, Dry Creek, and the Fresno River
- BNSF Alternative: BNSF railroad underpass at G Street
- Hybrid Alternative: Franklin Road overcrossing, Bear Creek, and the Chowchilla River
- HMFs: The portion of the HST alignment between Atwater and the City of Merced could be more prone to unstable soils because of the high groundwater conditions relative to sections of the alignment to the south.

Under NEPA these impacts are considered moderate because the risks are predictable and avoidable through design standards. However, with implementation of normal design standards and guidelines, these risks will be addressed during construction, thereby reducing NEPA risks to

Soil Settlement

Magnitude of settlement: New loads on soft clayey soils could result in large vertical movement and, to a lesser extent, horizontal movement of the soil. For purposes of these discussions, settlement in excess of a couple inches is considered large for typical elevated structures, while settlement for embankments would be large if it exceeded 4 to 6 inches.

Rate of settlement: In clayey soils, the rate of settlement can be slow, resulting in movement over weeks and months. Detailed geotechnical studies are conducted to evaluate both the rate and amount of settlement and to identify appropriate mitigation methods.

being negligible and less than significant under CEQA. Manuals, such as the *Field Guide to Construction Site Dewatering* (Caltrans 2001) describe BMPs that address this impact. With implementation of standard construction and engineering design standards and practices that address soft deposits of silty or clayey soils, the potential for soil settlement affecting structures or utilities adjacent to construction areas would be negligible under NEPA and less than significant under CEQA.

Another potential source of settlement is from displacement of retaining walls in retained cut segments of the track alignment. This can occur where retaining walls support earth pressures and nearby building loads. If the pressures on the retaining wall are underestimated and the wall deforms outward, soil behind the wall could settle, resulting in damage to structures supported on the soil or utilities located in the soil. The final design would incorporate AASHTO and AREMA methods for estimating wall loads to minimize the risk of damage to nearby structures. Incorporating engineering design features that address soft deposits of silty or clay soils would render the potential for soil settlement a negligible impact under NEPA and a less than significant impact under CEQA.

Soil Erosion

Accelerated soil erosion, including loss of topsoil, could occur as a result of project construction on erosion-prone soils. Soils that have a high potential for water or wind erosion were identified for alternatives, including the north-south alignments, wyes, and stations, and HMFs (see Section 3.6.2), as shown in Figures 4-1 and 4-2. With the development of any alternative, the potential for more surface water runoff exists during construction when existing vegetation is removed and soils are exposed to either wind or water erosion. Surface water runoff could also result from the construction of temporary impermeable work surfaces.

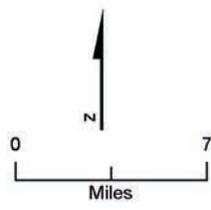
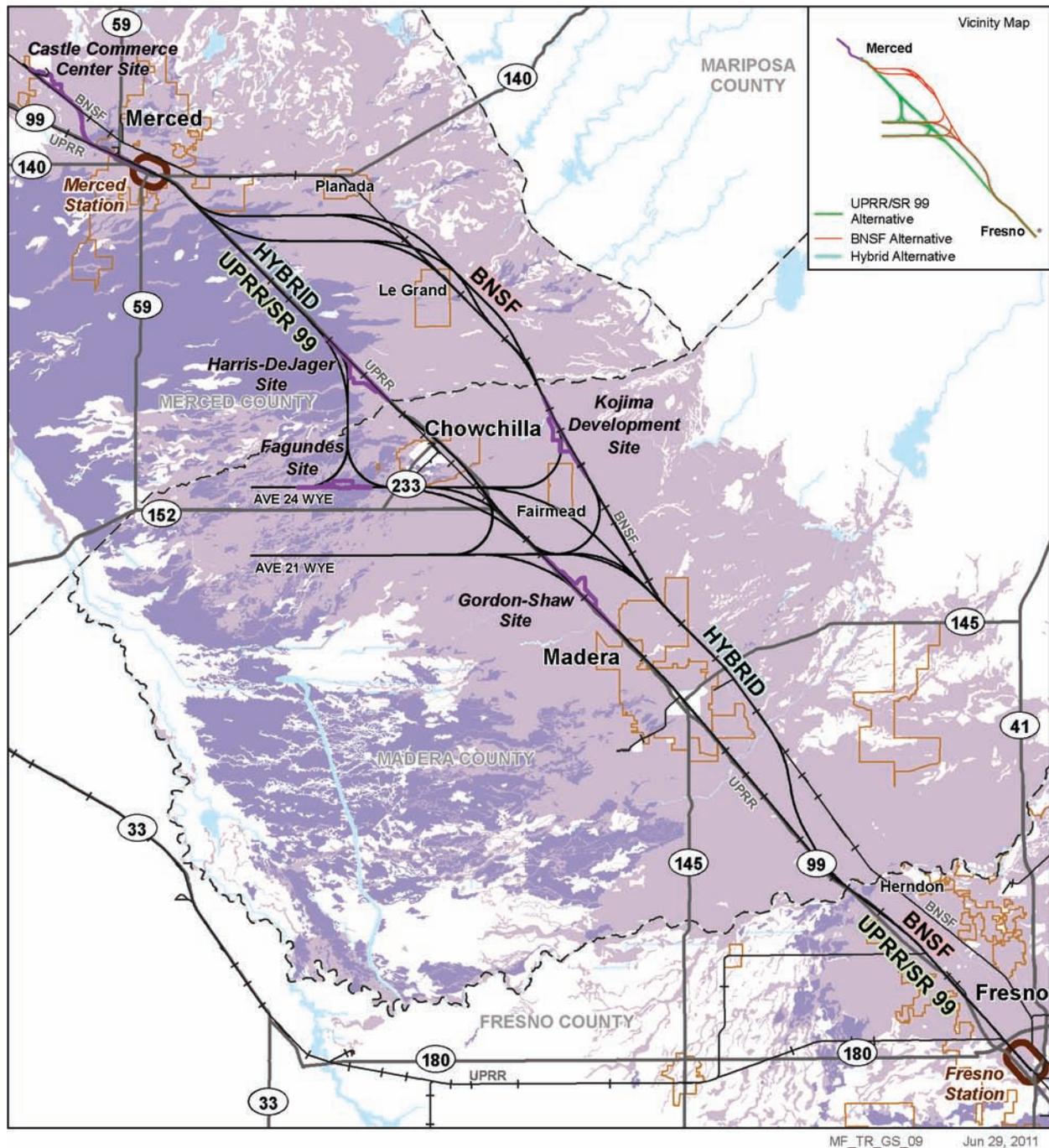
If exposed soils are not protected from wind or water erosion, such as stockpiling of excavation materials during construction, the topsoil could erode and cause indirect impacts on water quality and loss of high value soil, which collectively would result in a substantial indirect effect. The potential for erosion from water increases slightly from west to east. Methods that involve more exposure of the ground during construction would have greater risks from water and wind erosion. Some methods of construction, such as elevated structures located on deep foundations, would have limited potential for erosion because of the limited exposed earth, while other methods, such as at-grade segments, could have greater risk. Both the retained cut and retained fill have limited severity of risk because of the limited area of exposed earth during construction.

Under NEPA, the impact would be substantial because of the prevalence of soils that are susceptible to wind and water erosion and other indirect effects resulting from erosion. Again, with the implementation of standard construction practices, such as those listed in the Caltrans' *Construction Site Best Management Practices (BMPs) Field Manual and Troubleshooting Guide* (Caltrans 2003a) and the *Construction Site Best Management Practice (BMP) Manual* (Caltrans 2003b) and the that reduce the potential for erosion, the risk of these impacts would be negligible under NEPA and less than significant under CEQA.

Difficult Excavations due to Hardpan and Shallow Groundwater

Upper layers of soil can contain cemented zones and hardpan that can be very difficult to excavate with conventional machinery. Excavations in these soils may require blasting if conventional machinery is not adequate. These soils are typical in this area and contractors are familiar with methods to handle excavations in hardpan.

Excavations in loose, cohesionless deposits that extend below groundwater levels could also result in difficult excavations. At these locations hydrostatic pressures can result in instabilities of the excavation side-slopes or heave of the excavation base, leading to loss of ground support. These conditions can be encountered in localized areas such as at river crossings. Shallow groundwater between Atwater and Merced and localized, near surface deposits of loose, cohesionless soils could create areas of difficult excavation.



- HST Alignment
 - Potential Heavy Maintenance Facility
 - City Limit
 - Station Study Area
 - - - County Boundary
 - +— Railroad
- | | |
|--------------------------------------|----------|
| Soil Erodibility due to Water | Moderate |
| | High |

Figure 4-1
 Potential for Soil Erosion
 Due to Water

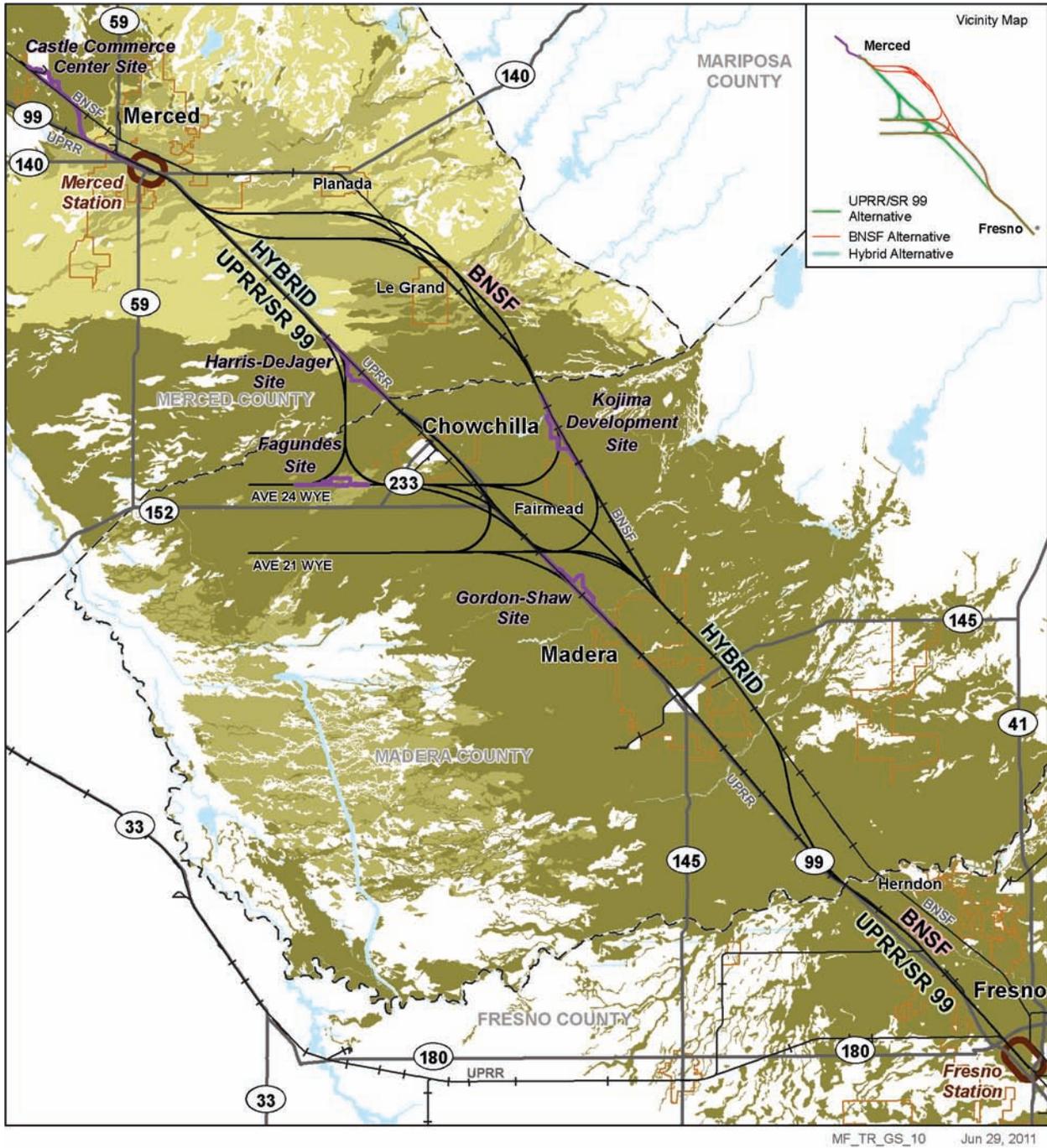


Figure 4-2
 Potential for Soil Erosion
 Due to Wind

Locations where retained cut alignment segments are planned would be most affected by hardpan and shallow groundwater conditions. Both the retained fill and at-grade design types would usually involve limited need to excavate the hardpan or work below the groundwater level, and deep foundations for elevated structures are conventionally constructed into hard geologic materials, such as rock, and below the groundwater.

With the implementation of methods in the Caltrans' *Construction Site Best Management Practices (BMPs) Field Manual and Troubleshooting Guide* (Caltrans 2003a) and the *Construction Site Best Management Practice (BMP) Manual* (Caltrans 2003b), these potential impacts would be negligible under NEPA and less than significant under CEQA.

4.3.2.2 Alignment Alternatives

Impacts during the construction period would be similar for the UPRR/SR 99, the BNSF, and the Hybrid alternatives because of similar topography (i.e., relatively flat-lying), geologic units, soils, and groundwater location, and levels of earthquake-induced ground shaking. The subtle difference between the three alternatives is the potential for higher water erosion for the HST alignments that are west of SR 99 over those that are east of SR 99. In general, the western alignments have more areas of soils with high water erosion potential (primarily in Merced County). As the distance from the mountains to the west increases, soils tend to be finer. This trend in finer grained soils to the west could also mean that the amount of unstable or settlement-prone soils increase slightly for the western alignments relative to the eastern alignments. Overall, soils are competent along all HST alignments except in isolated locations near rivers and streams.

Specific locations that have either soft fine-grained soils or loose-to-medium dense granular soils and could exhibit risks of bearing failures, slope instabilities, and excessive settlement are as follows:

- UPRR/SR 99 Alternative: Franklin Road overcrossing, Bear Creek, East Merced overhead, Miles Creek, Duck Slough Bridge, Deadman Creek, Dutchman Creek, Chowchilla River, Dry Creek, Fresno River, West Fourth Street overcrossing, Avenue 11 overcrossing, Avenue 8 overcrossing, and the San Joaquin River.
- BNSF Alternative: BNSF railroad underpass at G Street, Bear Creek Bridge, and Campus Park overhead.
- Hybrid Alternative: Franklin Road overcrossing, Bear Creek, East Merced overhead, Miles Creek, Duck Slough Bridge, Deadman Creek, Dutchman Creek, and Chowchilla River.

Areas of difficult excavation could occur where groundwater is shallow and localized, near surface deposits of loose, cohesionless soil occurs, such as between Atwater and Merced. The potential for encountering hardpan also is greater along the BNSF Alternative than in other locations.

4.3.2.3 HST Stations

Soils at the Merced and Fresno stations have a moderate potential for erosion by water. A moderate potential exists for wind erosion of soils at the Merced station, while soils at the Fresno station have a high potential for erosion due to wind. Although groundwater is shallower at the Merced station (at about 50 feet below ground compared to the Fresno station, which is between 80 and 90 feet below ground), little difference in construction or foundation behavior is expected at either location, unless deep basements are used for automobile parking. If deep parking garages were used, the Merced station could result in more dewatering for subsurface excavations, lower stability for excavation slopes, and a greater potential for settlement under construction loads than the Fresno station. There is one natural waterway crossing at the far northwestern portion of the study area for the Merced station where difficult excavation could be encountered. The Fresno station does not have any natural waterway crossings.

4.3.2.4 Heavy Maintenance Facility Alternatives

Potential for erosion by water is highest at the Fagundes HMF site; the other HMF sites have a moderate potential. Overall, the HMF with the lowest potential effect due to soils is the Castle Commerce Center site because of it is a developed site with drainage facilities. The Fagundes, Gordon-Shaw, and Kojima Development HMF sites have the highest potential for high wind and water erosion susceptibility due to the soil types present. Groundwater is shallowest at Castle Commerce Center, including the track connecting to the Downtown Merced Station, compared to the other HMF sites, and this condition could result in more dewatering for subsurface excavations, lower stability for excavation slopes, and a greater potential for settlement under construction loads. There are two natural waterway crossings at the Castle Commerce Center and Gordon-Shaw HMF sites where difficult excavation could be encountered. The other three HMF sites have no natural waterway crossings or only one waterway crossing.

4.3.3 Project Impacts

4.3.3.1 Common Geology, Soils, and Seismicity Impacts

Project (operational) impacts related to geology, soils, and seismicity were identified based on conceptual plans for design. Similar to the construction period impacts, geologic risks during the project are only different in that there is a much longer exposure period. This longer exposure period increases the potential risks from localized deposits of unstable soils, areas with potential for soil settlement, soils with moderate-to-high shrink-swell potential and high corrosivity potential, slumps and slope failures, seismic ground motions, and the risks from secondary seismic hazards associated with large seismic-induced ground motions. Each of the risks described below will be addressed during the normal course of engineering design.

Unstable Soils Resulting in Onsite or Offsite Slumps and Surficial Slope Failures

The potential for impacts from unstable soils during operation is the same as that described for construction, except that the exposure period increases. With the longer exposure period, the potential for creep- or groundwater-related soil failures increase. The unstable soils consist of loose or soft deposits of sands, silts, and clays that can occur on a localized basis and are likely to be more prevalent near river and stream crossings. Potential locations are the same as discussed for construction.

The adverse impacts from soft or loose soils would affect some design types more than others. For instance, unstable soils would represent a greater risk to locations where retained fills are planned than to at-grade segments of the alignment because of the much greater load that retained fills would impose on the unstable soil. Typically, elevated structures supported on deep foundations are specifically designed to handle soft near-surface soils, and retained cuts can accommodate soft soil conditions. Where soft soil conditions are combined with the potential for small slumps and slope failures, the severity of the risk increases. In these locations, the potential impact of loss in bearing or additional soil loads associated with the slump or slope failure would also be considered.

Under NEPA, this impact is considered to be moderate because the locations where unstable soils are likely to be encountered are known and readily remedied through design criteria for these conditions. The HST project design would incorporate design methods that consider the short- and long-term impacts of unstable soils on the HST and nearby facilities. Where appropriate, engineered ground improvements, including regrading or groundwater controls, would be implemented to avoid long-term impacts from unstable soils. Implementation of these methods during final design would meet standards of design and building code requirements to provide either sufficient bearing capacity and slope stability or design measures that protect the facility from loads associated with unstable soils. With implementation of these design measures, the potential impacts from soft or loose soils would be negligible under NEPA and less than significant under CEQA.

Soil Settlement

Project facilities and adjacent structures could require periodic maintenance or become damaged during operation of the project as a result of soil settlement. Soil settlement could occur during operation of the project at locations where soft deposits of silty or clay soils are subjected to new earth loads, as might occur with approach fills for elevated guideways and retained-fill segments, or for track subgrade and ballast materials that are placed to meet track grade requirements. If earth loads are large, these soft soils could result in large vertical and, to a lesser extent, lateral movements under the weight of the increased earth loads, damaging the new infrastructure as it settles. For purposes of these discussions, settlement (movements) in excess of a couple inches is often considered large for elevated structures and 4 to 6 inches for embankments. The zone of influence from the new earth loads could extend into adjacent property, resulting in indirect impacts as settlement causes displacement of adjacent sidewalks, streets, and utilities. Large loads associated with retained-fill segments of the alternatives potentially result in greater severity of risk for soil settlement at soft soil sites. Elevated structures on deep foundations, at-grade, and retained cut segments of the alternatives represent minimum risk because they involve limited addition of new loads to the existing earth.

There are a number of locations along the project footprint that would require new earth fills in areas that are potentially underlain by settlement-prone (loose or soft) soils. These specific locations would be identified during design and preconstruction investigations. Potential locations are the same as identified for construction. The potential consequence of excessive settlement represents a high risk to HST travel if unattended. However, settlement is a typically a slow process that with periodic maintenance can quickly be remedied by periodic dressing and or reballasting where required to maintain a safe track profile.

Under NEPA, this impact is considered to be moderate because of the limited number of locations where settlement-prone soils are likely to be encountered. As part of project commitments, the HST project design incorporates ground improvements and foundations that are resistant to settlement and would meet standards of practice and building code requirements. In addition, additional fill material from other sources would be imported, as necessary. With implementation of these standard engineering design methods, the potential risk of excessive ground settlement would be minimized and the impact would be considered negligible under NEPA and less than significant under CEQA.

Moderate to High Shrink-Swell Potential

Construction of the project on soils with moderate to high shrink-swell (expansive) potential could result in damage to the facilities during operation of the project. The potential for shrink-swell represents a significant risk to the operation of the track system and the track right-of-way for long-term operations for some of the design options. A consequence of shrink-swell potential includes differential track movement.

This type of impact is more critical to locations with at-grade segments than to elevated structures on deep foundations, retained fill, and retained cuts. The earth loads associated with at-grade segments of the alternatives may not be sufficient to overcome swell potential, and this swell would likely be variable along the HST north-south alignments, wyes, stations, and HMFs, leading to differential movement of the track system.

This impact is considered substantial for all alternatives and HMF sites because most of the soils located in the upper 5 feet of the soil profile were generally found to have moderate-to-high shrink-swell potential, as shown in Figure 4-3. Under NEPA, the impact is considered substantial because this impact could result in loss of life or substantial property damage if not adequately addressed during design and construction.

Because of the shrink-swell potential risk, the project commitment includes moisture conditioning, removal of soils that exhibit high shrink-swell potential, or mixing soils with additives to reduce shrink-swell potential. Soils with high shrink-swell characteristics that are removed would be replaced with engineered fill that does not exhibit these undesirable characteristics. Implementing project design

features and BMPs during construction and maintaining them during operation would render risks from shrink-swell soils to a negligible impact under NEPA and a less than significant impact under CEQA.

Moderate to Highly Corrosive Soils

Construction of the project on moderate to highly corrosive soils could result in damage to the facilities during operation of the project. The potential for corrosion to uncoated steel and concrete represents a significant risk to the operation of the track system and the track right-of-way for long-term operations. Consequences of corrosion could include eventual loss in the structural capacity of the track connections or culvert drainage systems below the track, or damage to switches or other moving parts of the track system.

The retained fill and at-grade segments would be most vulnerable to corrosive soils. The retained cut would generally have sufficient earth between the corrosive soil and the track to protect it from corrosion, and the elevated structures supported on deep foundations would use concrete that is resistant to concrete corrosion. As necessary, final designs would include epoxy-coated steel or double corrosion-protection ground anchors to avoid long-term corrosion issues.

This impact is considered substantial because the upper 5 feet of most soil types within the study area have a moderate-to-high corrosivity to uncoated steel and concrete, as shown in Figures 4-4 and 4-5. Under NEPA, the impact is considered substantial because this impact could result in loss of life or substantial property damage if not adequately addressed during design and construction.

Because of the corrosion risk, the project commitment includes soil improvement by removing the upper 5 feet of soils that exhibit high corrosivity characteristics and replacing the excavated soils with soils that do not exhibit these characteristics, or through the selection of appropriate material properties. Active and passive corrosion-protection systems could also protect embedded and exposed steel structures from corrosion. Implementing project design features and BMPs during construction and maintaining them during operation would render the risks from corrosive soils a negligible impact under NEPA and a less than significant impact under CEQA.

Slumps and Slope Failures

Slopes along some rivers and streams could fail from either additional earth loads at the top of the slope, undercutting by stream erosion at the toe of the slope, or from additional seismic forces during a seismic event. These failures could endanger people and onsite and offsite structures if the HST track were damaged by the failure. Most slopes are less than 10 feet in height; therefore, the likelihood of slope failures is generally very low. However, slopes at Berenda Creek and the San Joaquin and Fresno Rivers are 15 feet tall or greater, with the tallest at the San Joaquin River at 50 feet in height, resulting in a significant risk. Of the two rivers, the San Joaquin River has the higher risk, given the estimated 50-foot height of the slopes.

The consequence of slope failure would be either loss of bearing support to the track facilities or increased load on structures that are in the path of the slope failure. The former of these represents the higher risk because of the flat topography along the alternatives. Loss in bearing support would affect at-grade and retained-fill segments more than retained cuts and elevated structures supported on deep foundations. In the case of elevated structures, the location of the foundation would be sited during final design to avoid the area of slope failure.

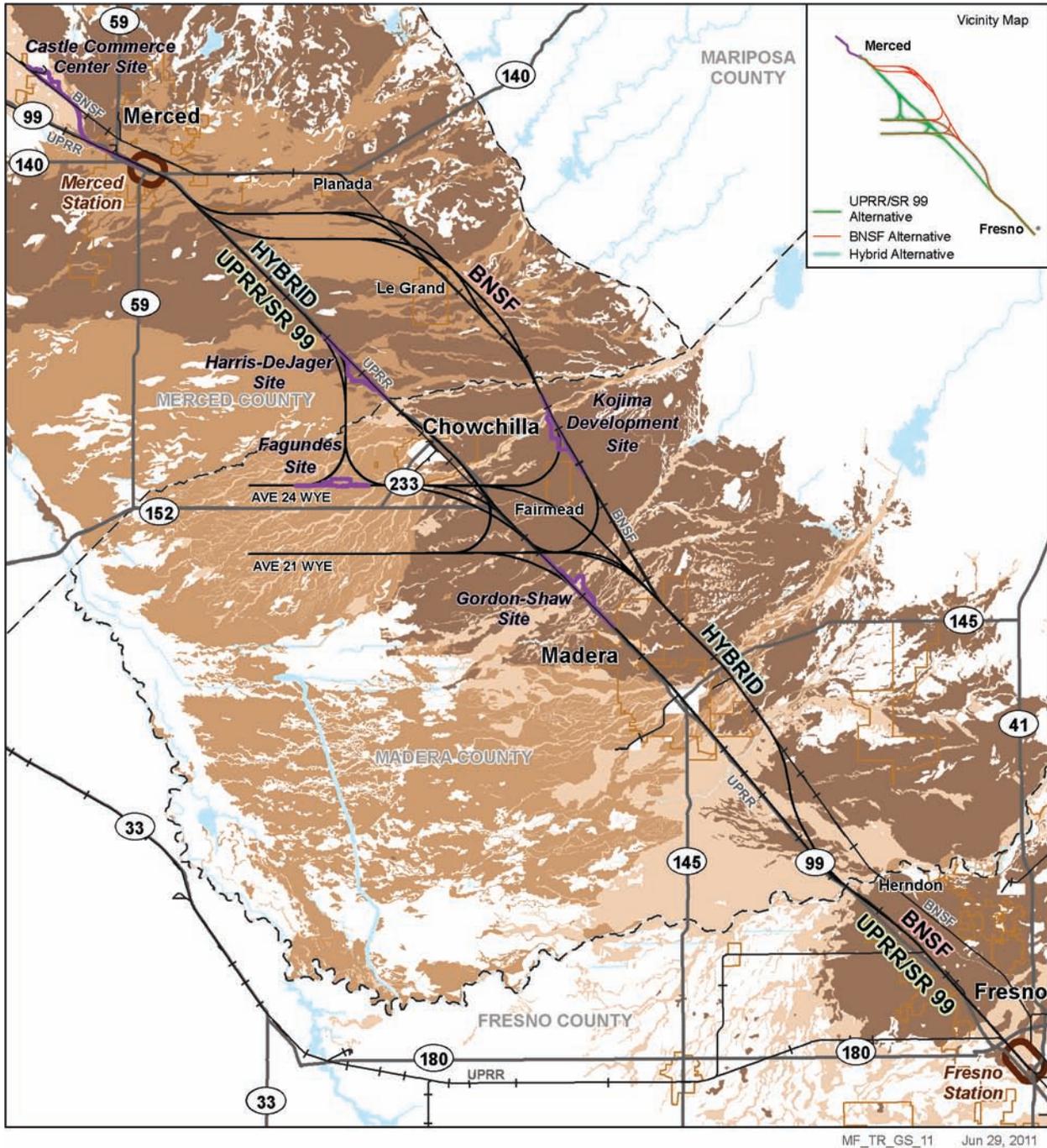


Figure 4-3
 Potential for Soil Shrink-Swell

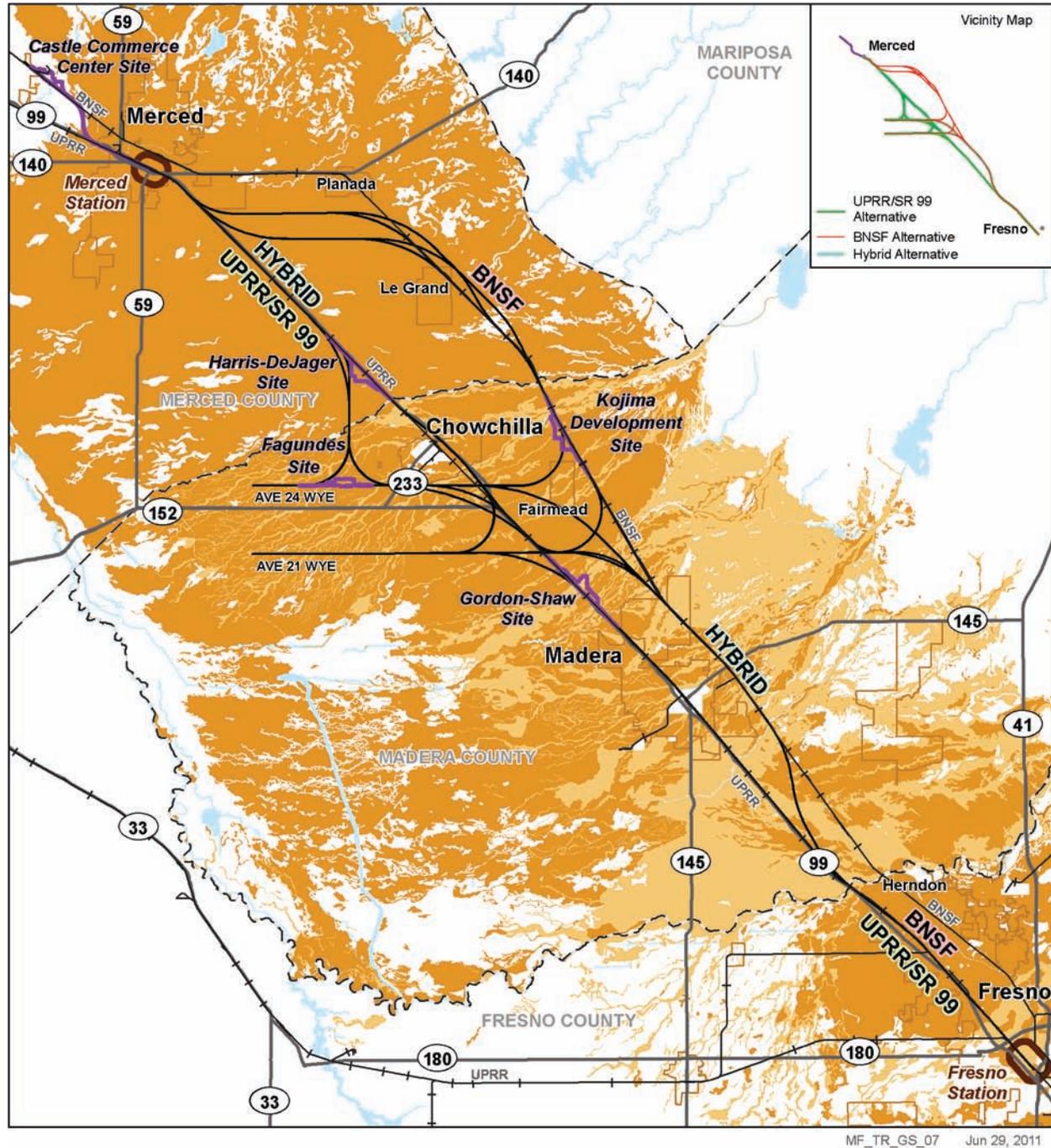
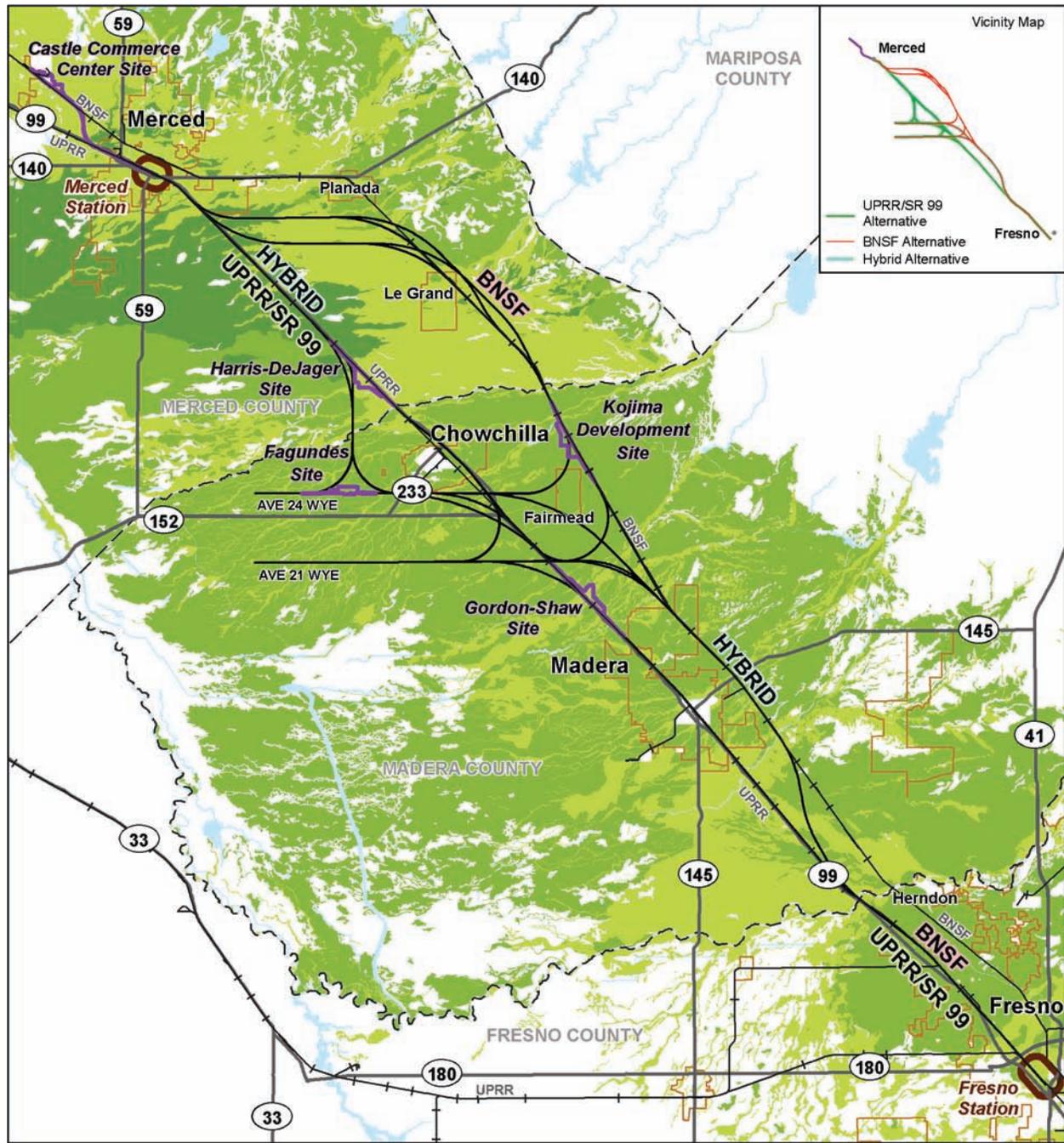
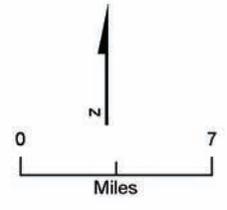


Figure 4-4
 Potential for Soil Corrosion of
 Uncoated Steel



MF_TR_GS_08 Jun 29, 2011



- HST Alignment
 - Potential Heavy Maintenance Facility
 - City Limit
 - Station Study Area
 - - - County Boundary
 - +— Railroad
- | Soil Corrosivity to Concrete | |
|------------------------------|----------|
| | Low |
| | Moderate |
| | High |

Figure 4-5
 Potential for Soil Corrosion of Concrete

Under NEPA, this impact is considered to be moderate because of the limited number of locations having slopes that could fail, and preventative measures are routinely addressed by geotechnical engineers during design. As part of the project commitments, the HST project design and construction address slope stability by incorporating Caltrans, AREMA, and AASHTO engineering standards and criteria. Detailed slope stability evaluations would be conducted and design measures, such as structural solutions (e.g., tie backs, soil nails, or retaining walls) or geotechnical solutions (e.g., ground improvement or regrading of slopes), would be implemented during construction, as appropriate, to reduce the potential for future slumps and slope failures. These measures and solutions would change the impact for slope failure at the Berenda Creek and the Fresno and San Joaquin Rivers to negligible under NEPA and less than significant under CEQA.

Seismic-Induced Ground Shaking

The level of ground shaking is estimated to have a peak ground acceleration at the ground surface of up to 0.35g. This level of shaking would result in significant loads to structures supported on the soil, and could result in secondary seismic hazards such as liquefaction, liquefaction-induced slope failures, and post-seismic settlement as liquefaction-induced water pressures dissipate. The level of ground shaking could vary along the alignment depending on the amount of ground motion amplification or de-amplification within specific soil layers; however, the likely level of seismic-induced ground motion is sufficient to represent a substantial impact regardless of the specific location.

The level of ground shaking represents a critical hazard to all design types. Elevated structures supported on deep foundations can be designed for moments and shear forces associated with the ground shaking, while the retaining walls for retained-fill earth structures can be designed for the inertial response of the retained soil. Similar to the retained-fill design requirements, retained cuts can be designed for increased earth pressures from ground shaking.

Another key consideration is the response of the operating HST to a seismic event that shakes the track. Movement of the track will be transferred into the train. The train cars, spring system for the train, and tracks need to be appropriately configured to resist the resulting inertial response of the train, while traveling at a high speed. The project is currently developing criteria for meeting seismic loading demands. Available information for HSTs in seismically active areas besides California, such as Japan and Taiwan, suggests that the California HST would be able to satisfy life-safety requirements for the earthquake ground motions used for HST design by implementing normal train and track systems.

Under NEPA, the impact is considered substantial because this impact could result in loss of life or substantial property damage if not adequately addressed during design and construction. As part of the project commitments, HST design would address seismic-induced ground shaking by specifying minimum seismic loading requirements for the train performance, by specifically evaluating the response of the track system, including elevated structures, and by confirming that the soil provides sufficient support to the track. Detailed seismic response evaluations would be conducted, and design measures, such as enhanced structural detailing, more system redundancy, or special ground motion isolation systems would be implemented, as appropriate, to reduce the potential for failures from inertial forces resulting from the ground motions. Implementing project design features would render risks from seismically induced ground-shaking a negligible impact under NEPA and a less than significant impact under CEQA.

Secondary Seismic Hazards

One of the primary consequences of strong ground shaking could be liquefaction of loose, cohesionless soils located below the groundwater table. The potential for liquefaction and related hazards (such as settlement from densification of loose soils, instability of steep slopes, or increased earth pressures on retaining walls) would be highest where groundwater is shallow. Such conditions exist between Atwater and the City of Merced, where groundwater tends to be less than 50 feet in depth, and next to rivers and streams. The consequences of liquefaction could be loss in soil bearing support, ground settlement, and instability or flow of slopes located in liquefiable soils.

The effect of these secondary seismic hazards could vary. Retained fills and at-grade structures could be more affected from loss of bearing support. Elevated structures located on deep foundations are capable of withstanding near-surface liquefaction, and retained cut structures can be designed for increased loads from liquefied soil. Structures located on or in the path of moving ground associated with slope instability or flow can be designed for earth loads of the moving soil.

Site-specific geotechnical investigations during design and preconstruction are necessary at these locations to determine whether the type and density of the soil result in conditions that would be susceptible to liquefaction and are in need of stabilization. Detailed slope stability evaluations would also be conducted and design measures, such as ground improvement, use of retaining walls, or regrading of slopes, would be implemented during construction, as appropriate, to reduce the potential for future slumps and slope failures. These design measures would render the risk of secondary seismic events to a negligible impact under NEPA and a less than significant impact under CEQA.

A seismically induced dam failure on one or more of the dams would be an unlikely event as the seismic event would need to be large enough to cause catastrophic damage to the dam structure and the retained water would need to be at a maximum operating elevation to cause inundation of the areas shown in Figure 3-6. Because dam failure is an unlikely event, the risk of dam failure is a negligible impact under NEPA and a less than significant impact under CEQA.

4.3.3.2 Alignment Alternatives

Impacts during project operation would be similar for the UPRR/SR 99, the BNSF, and the Hybrid alternatives because of similar geologic, soils, and seismic characteristics. As the distance from the mountains to the west increases, soils tend to be finer. This trend in finer grained soils to the west could also mean that the amount of unstable or settlement-prone soils increase slightly for the western alignments relative to the eastern alignments. Overall, soils are competent along all HST alignments except in isolated locations near rivers and streams. The location of softer soil and shallow groundwater would affect retained fill more than at-grade segments for soft soil conditions and retained cuts for high groundwater elevations.

Other potential impacts such as shrink-swell characteristics, soil corrosion, seismic ground motions, liquefaction potential, and other effects of earthquake loading are similar among all alternatives during the project duration.

4.3.3.3 HST Stations

The soils at the Merced station have a moderate shrink-swell potential, and the majority of the soils at the Fresno station have a low shrink-swell potential. Soil corrosivity is low to concrete and very high for steel at the Downtown Merced station site, and the majority of the soils at the Downtown Fresno station site have a low corrosivity to concrete and a moderate corrosivity to steel. There is one natural waterway crossing at the Downtown Merced station and no natural waterway crossings at the Fresno station. Therefore, the Merced station has a slightly higher potential for small slumps or slides and an increased presence of soft soils and shallow groundwater, which would, in turn, increase the potential for soil settlement.

4.3.3.4 Heavy Maintenance Facility Alternatives

There are two natural waterway crossings at the Castle Commerce Center and Gordon-Shaw HMF sites. The other three HMF sites have no natural waterway crossings or only one waterway crossing. Therefore, the Castle Commerce Center and Gordon-Shaw HMF sites have the potential for small slumps or slides and an increased presence of soft soils and shallow groundwater, which in turn would increase the potential for soil settlement.

5.0 Standard Engineering and Design Measures Incorporated as Part of the HST Project

There would be no project-level mitigation measures required. Project design would incorporate design measures and BMPs based upon federal and state regulations and on the Statewide Program EIR/EIS (Authority and FRA 2005). Site-specific explorations would be carried out as design work progresses so that the Authority can incorporate site-specific engineering solutions that adhere to standard engineering design practices and codes into the design to reduce risks associated with geology, soils, and seismicity. The standard engineering design guidelines and standards are listed in Section 3.3.4.

To manage geologic, soils, and seismic hazards, projects implement specific design measures to reduce and avoid impacts during construction and operation. These practices include the following:

- **Limit Groundwater Withdrawal:** Control the amount of groundwater withdrawal, re-inject groundwater at specific locations, or use alternate foundations to offset the potential for settlement. This control is important for locations with retained cuts in areas of high groundwater and where existing buildings are located near the depressed track section.
- **Monitor Slopes:** Incorporate slope monitoring into final design where a potential for long-term instability exists from gravity or seismic loading. This practice is important near at-grade sections where slope failure could result in loss of track support or where slope failure could result in additional earth loading to foundations supporting elevated structures.
- **Suspend Operations Before and After Earthquake:** Use motion-sensing instruments to provide ground-motion data; implement a control system to shut down HST operations temporarily during or after an earthquake to reduce risks. Monitoring is appropriate for any location where high ground motions could damage the HST track system. Candidate locations would include elevated guideways, retained earth, retained cut, and at-grade segments.
- **Conduct Geotechnical Inspections:** Prior to and throughout construction, conduct geotechnical inspections to verify that no new, unanticipated conditions are encountered and to determine the locations of unstable soils in need of improvement.
- **Improve Unstable Soils:** For unstable soils the risk of ground failure can be minimized or avoided by various methods. If the soft or loose soils are shallow, they can be excavated and replaced with competent soils. Where unsuitable soils are deeper, ground improvement methods such as stone columns, cement deep soil mixing (CDSM), or jet grouting could be used. Alternately, if sufficient construction time is available, preloading in combination with prefabricated vertical drains (wicks) and staged construction can be used to gradually improve the strength of the soil without causing bearing capacity failures. Both over-excavation and ground improvement methods have been successfully used to improve similar soft or loose soils. The application of these methods is most likely at stream and river crossings, where soft soils could occur; however, localized deposits could occur at other locations along the alignment. The ground improvement or over-excavation methods may also be necessary at the start of approach fills for elevated track sections or retained earth segments of the alignment if the earth loads exceed the bearing capacity of the soil. Alternately, at these locations earth fills might be replaced by light-weight fill such as extruded polystyrene (geofoam), or short columns and cast-in-drill hole (CIDH) piles might be used to support the transition from the elevated track to the at-grade alignment.
- **Improve Settlement-Prone Soils:** Settlement-prone soils are improved prior to facility construction. Ground improvement is used to transfer new earth loads to deeper, more competent soils. Another alternative is to use preloads and surcharges with wick drains to accelerate settlement within areas that are predicted to undergo excessive settlement. By using the preload and surcharge

with wick drains, settlement would be forced to occur more quickly, allowing construction to proceed at an earlier date. The application of these methods is most likely at stream and river crossings, where soft soils are more likely to occur. Where groundwater is potentially within 50 feet of the ground surface, any below-ground excavations encountering a groundwater table would use well points in combination with sheetpile walls to limit the amount of settlement of adjacent properties from temporary water drawdown. Alternately, water can be reinjected to make up for localized water withdrawal.

- **Prevent Water and Wind Erosion:** Many engineering methods exist for controlling water and wind erosion of soils. These include use of straw bales and mulches, revegetation, and covering areas with geotextiles. Where the rate of water runoff could be high, rip rap and rip rap check dams could be used to slow down the rate of water runoffs. Other BMPs for water are discussed in the *California HST Merced to Fresno Section Draft Project EIR/EIS Hydrology and Floodplains Technical Report* (Authority and FRA 2011). Implementation of these methods is important where large sections of earth would be exposed during construction, such as for retained cut segments.
- **Modify or Remove and Replace Soils with Shrink-Swell Potential and Corrosion Characteristics:** One option is to excavate soils that represent the highest risk and replace with engineered fill that does not exhibit these characteristics. Other alternatives might be to moisture conditioning the soil to reduce the shrink-swell potential or use corrosion-protected materials. In locations where shrink-swell potential is marginally unacceptable, soil additives would be mixed with existing soil to reduce the shrink-swell potential. The decision whether to remove or treat the soil is made on the basis of specific shrink-swell potential or corrosivity characteristics of the soil, the additional costs for treatment versus excavation and replacement, as well as the long-term performance characteristics of the treated soil. This practice is important for at-grade segments of the alignment because these are most likely to be affected by shrink-swell potential or corrosive soils.
- **Evaluate and Design for Large Seismic Ground Shaking:** Detailed seismic studies will need to be conducted to establish the most up-to-date estimation of levels of ground motion, including use of updated Caltrans seismic design criteria in the design of any structures supported in or on the ground. These design procedures and features reduce the potential that moments, shear forces, and displacements that result from inertial response of the structure lead to collapse of the structure. In critical locations, pendulum base isolators can reduce the levels of inertial forces. New composite materials can enhance seismic performance.
- **Secondary Seismic Hazards:** As discussed above, various ground improvement methods can be implemented to reduce or avoid the potential for liquefaction, liquefaction-induced lateral spreading or flow of slopes, or post-earthquake settlement. Ground improvement around CIDH piles improves the lateral capacity of the CIDH during seismic loading. CDSM or jet grouting develop resistance to lateral flow or spreading of liquefied soils.

6.0 NEPA Impacts Summary

The Results of this environmental assessment identified NEPA impacts for both the No Project Alternative and the HST project alternatives. The No Project Alternative represents changes in local conditions from infrastructure and development projects that result in greater water or wind erosion, loss of valuable topsoil, or constraints on the potential for oil and gas resource development that would result without the project. NEPA impacts that could develop as a result of the HST alternatives include the following:

- Construction and long-term operation of the project alternatives, stations, and HMF on soft or loose soils could result in onsite or offsite slumps and small slope failures at stream crossings, instability of cut-and-fill slopes required for the track, or collapse of retaining structures associated with retained cuts or retained fills, the effects of which are negligible with standard engineering design measures.
- Settlement of soft or loose soil supporting structures and trackway could result in damage during construction and operation. The risk of this hazard along the alignments for elevated structures, retained cuts, retained fills, and at grade structures, as well as at the HMFs, would be negligible with design measures, for example, excavating underlying settlement-prone (loose or soft) soils and augmenting with new earth.
- Wind or water erosion of soil during both construction and operation are considered negligible with implementation of standard design measures and BMPs.
- The potential impacts of shrink-swell and corrosion on uncoated steel and concrete and the operation of the track system and the track right-of-way for long-term operations would be negligible by implementing standard design measures, for example, excavating underlying corrosive soils and augmenting with an imported soil base.
- The potential impacts of slope failure at stream crossings would be negligible with implementation of standard geotechnical engineering design.
- Effects from seismically induced ground motion are expected to be negligible with implementation of standard design measures.

7.0 CEQA Level of Significance

With implementation of standard engineering design measures and BMPs, impacts on elevated structures, retained cuts, retained fills, and at-grade segments of each alternative would be less than significant. Therefore, mitigation measures are not required.

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9.0 Preparer Qualifications

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Jennifer Krenz-Ruark is a soil scientist specializing in land use and classification of soils. She earned an M.S. in soil science from Purdue University and a B.S. in natural resource management (with minors in water resources and soil science) from the University of Wisconsin-Stevens Point. She has more than 9 years of experience in the field of soil science, specializing in field characterization and classification, soil survey interpretation, and land use analysis.

Kathy Rose holds B.S., M.S., and Ph.D. degrees in soil science, and is a certified professional soil scientist. Dr. Rose has approximately 20 years of combined experience in academic research with the University of California system, water quality regulatory experience with the State of California, and environmental consulting.