3.9 Geology, Soils, and Seismicity

3.9.1 Introduction

This section identifies geologic, soils, and seismic conditions that could affect or be affected by the project. The section describes the regulatory setting, affected environment, impacts, and possible mitigation measures associated with the geology, soils, and seismicity of the project environment. The discussion of impacts considers the consequences of the project on geology, soils, and seismicity and how geology, soils, and seismicity would affect the project. The *Fresno to Bakersfield Section: Geology, Soils, and Seismicity Technical Report* (Authority and FRA 2012) provides detailed geologic, soils, and seismic information. In addition, a more detailed discussion of geotechnical conditions is presented in the *Fresno to Bakersfield Geologic and Seismic Hazards Report* (Authority and FRA 2011a).

The Program EIR/EIS documents concluded that in the Fresno to Bakersfield area the project would have a low potential for impacts due to the prevailing geology, soils, and seismicity. Design practices were selected to reduce the potential effects on the project from primary geologic hazards, such as major fault crossings, oil fields, and landslide areas. Design practices were also selected as the primary means of reducing potential impacts with site-specific origins based on detailed geotechnical studies, such as ground shaking, fault crossings, slope stability/landslides, areas of difficult excavation, hazards related to oil and gas fields, and mineral resources. The project incorporates design standards from 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 California Building Code, which per Title 24 California Code of Regulations (CCR) is based on the 2009 International Building Code (IBC), to address the identified geologic and soil conditions.

Geologic, soils, and seismic hazards that could affect the design, construction, and operation of the project include unstable slopes, soil settlement, accelerated erosion, expansive and corrosive soil properties, and earthquake-induced ground liquefaction and slope destabilization. Because they do not present a risk in the Fresno to Bakersfield Section, discussions that are omitted from this analysis include those related to the following:

- Landslides. The topography along the project alignments is flat and there is no evidence of landslides.
- Volcanic ash can fall from a volcanic eruption within the Mono Lake Long Valley Volcanic Area. The probability of occurrence of volcanic activity is very low (1% per year) according to the U.S. Geological Survey (USGS), and the prevailing wind is away from the project site, making the chance of ash fall very low.
- Seiches and tsunami flooding. No oceans, bays, or other bodies of water sufficient to result in a damaging seiche or tsunami occur near the project alignments.
- Excavation in rock. No rock excavation would occur because the depth of bedrock in the San Joaquin Valley is estimated to be several thousand feet below the ground surface.

Certain geologic and soil conditions depend on the proximity to streams and rivers; these are discussed in Section 3.8, Hydrology and Water Resources. Section 3.11, Safety and Security, addresses the earthquake safety of the high-speed train (HST) system.

Construction of this project requires substantial quantities of borrow material for use as track ballast and subgrade materials, as fill for embankments and approaches to elevated structures, and as aggregate for concrete and road construction. The Fresno to Bakersfield Section of the

HST project would require approximately 1,700,000 tons of aggregate for ballasted track, approximately 1,000 tons of aggregate for slab track, and 11,300,000 cubic yards of fill (assuming no fill is provided by project excavation). The Fresno to Bakersfield HST EIR/EIS evaluates two types of track construction, construction of the track using ballast (assumed for at-grade sections) and construction of the track using cast-in-place or precast concrete slabs (assumed for major structures). For the ballasted track, borrow requirements of the project were evaluated from five areas studied by the California Geological Survey (CGS 2006). These aggregate resources are typically mined from alluvial sources such as those found in the San Joaquin Valley. Sources of aggregate include Fresno (greater Fresno-Clovis metropolitan area), North Tulare County (Visalia/Tulare Area), South Tulare County (Portersville area), Bakersfield (Oildale to Tehachapi), and Palmdale. Permitted aggregate resources in these five areas equal approximately 370,000,000 tons (CGS 2012). Of these permitted resources, the proposed HST segment would require about 2.3 million tons, which represents approximately 0.6% of the currently permitted aggregate resources in these five areas.

The project would not rely on any one of these areas for all its aggregate or fill material. Based on this estimate, there would be sufficient aggregate and fill resources available to provide material for the project without harmfully depleting available sources. Therefore, project-specific borrow sites are not evaluated in the analysis of geology, soils, and seismicity.

Approximately 2.8 million cubic yards of ballast and 2.8 million cubic yards of sub-ballast material would be needed. Five potential quarries that provide ballast material were identified (Napa Quarry, Lake Herman Quarry, San Rafael Rock Quarry, Bangor Rock Quarry Site A, and Kaiser Eagle Mountain Quarry). All of these quarries have material available for project construction.

As discussed in Section 3.1.5 and the Executive Summary, the analysis in this chapter includes revisions based on design refinements and analytical refinements. Gray shading is used as a guide to help the reader navigate the revisions.

3.9.2 Laws, Regulations, and Orders

Key, state, and local laws and regulations that pertain to geology, soils, and seismicity and that are most relevant to the proposed project are summarized below. A list of key design standards and guidelines that could be used during design and construction of the project is available in Section 3.9.6, Project Design Features. Use of these guidelines and standards would help in avoiding or reducing potential risks from geologic and seismic hazards and adverse project impacts related to geology, soils, and seismicity.

3.9.2.1 State

Alquist-Priolo Earthquake Fault Zoning Act (Public Resources Code Section 2621 et seq.)

This Act provides policies and criteria to assist cities, counties, and state agencies in the exercise of their responsibility to prohibit 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)

This 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 Section 2710 et seq.)

This Act addresses 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.

Public Resources Code Sections 3000-3473

The Division of Oil Gas and Geothermal Resources (DOGGR) within the Department of Conservation oversees the drilling, operation, maintenance, and plugging and abandonment of oil, natural gas, and geothermal wells. DOGGR's regulatory program emphasizes the wise development of oil, natural gas, and geothermal resources in the state through sound engineering practices that protect the environment, prevent pollution, and ensure public safety.

3.9.2.2 Regional and Local

The State of California requires all cities and counties to adopt general 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. These plans also provide for protection from excessive soil erosion, slope failures, and hazards related to oil and gas fields. Table 3.9-1 provides a list of the plans and policies adopted by the cities and counties in the Fresno to Bakersfield Section. These local general plans and their policies were identified and considered in the preparation of this analysis.

Table 3.9-1
Local Plans and Policies

Policy Title	Summary
Fresno County	
Fresno County General Plan (Fresno County 2000a, 2000b)	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. • Chapter 5, Open Space and Conservation Element: 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: 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 geological unstable conditions that include seismic hazards, and geological and soil hazards. Policy HS-D.8 addresses shrink-swell or expansive soils. Policy HS-D.9 addresses soil erosion. Policies HS-D.10, HS-D.11, and SH-D.12 address unstable slopes, steep slopes, and landslide hazards.

Table 3.9-1
Local Plans and Policies

Policy Title	Summary
City of Fresno	
2025 Fresno General Plan (City of Fresno Planning and Development Department 2002)	Provides objectives and policies regarding mineral resources and public health and safety, including seismic protection, geological and soil hazards, and bluff preservation protection. • 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: 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.
Kings County	
2035 Kings County General Plan (Kings County Community Development Agency 2010a, 2010b)	Provides objectives and policies regarding mineral resources, land use compatibility, seismic protection, and geologic hazards. • Chapter 3, Resource Conservation Element: Objective H1.1 and Policies H1.1.1 and H.1.1.2 support extraction of mineral resources that does not harm the environment. Objective H1.2 and Policies H1.2.1 and H1.2.2 ensure that mineral resource extraction is compatible with the surrounding environment. • Chapter 7, Health and Safety Element: Goal A2, Objective A2.1, and Policies A2.1.1 through A2.1.6 attempt to minimize the loss of life and property due to geologic hazards.
City of Hanford	
City of Hanford General Plan Update 2002 (City of Hanford 2002)	Provides objectives and programs seeking to mitigate impacts of geologic and seismic hazards, protection from hazardous materials, and high-quality public safety. • Chapter 5, Hazards Management Element: Objective HZ 1, Policy HZ 1.2, and Programs HZ 1.2-A through HZ 1.2-C protect the city from hazards related to the environment.
City of Corcoran	
Corcoran General Plan 2025 (City of Corcoran 2007)	Provides objective and policies regarding emergency planning and response, fire protection, flooding, and public-safety standards. • Chapter 4, Safety Element: Objective A and Policy 4.27 require the city to adopt engineering standards related to seismic hazards.

Table 3.9-1
Local Plans and Policies

Policy Title	Summary
Tulare County	
Tulare County General Plan 2030 Update (Tulare County 2012a, 2012b)	Provides goals and policies regarding the protection of mineral resources, air quality, agriculture, biological, geologic and seismic hazards, emergency response, and hazardous materials. • Chapter 8, Environmental Resource Management Element: Goal ERM-2 and Policies ERM-2.1 through ERM-2.13 protect, conserve, and encourage the development of areas containing mineral resources. Goal ERM-3 and Policies ERM-3.1 through ERM-3.5 protect the current and future status of mineral extraction for the county while making sure to protect the environment. • Chapter 10, Health and Safety Element: Goal HS-2 and Policies HS-2.1 through HS-2.8 reduce the risks to life and property from seismic and geologic hazards.
Kern County	
Kern County General Plan (Kern County Planning Department 2009a, 2009b)	Provides goals and policies related to minimization of loss of life and property, geologic hazards, emergency response, and protection of natural resources and oil and gas. • Chapter 1, Land Use, Open-Space, and Conservation Element: Goals 1.9.1 and 1.9.2, Policies 1.9.14 and 1.9.25, implementation measures 1.9.H and 1.9.K promote compatible uses on or next to mineral and oil and gas lands. • Chapter 4, Safety Element: Goals 4.3.1 and 4.3.2, Policy 4.3.1, and implementation measures 4.3.A through 4.3.L minimize damage and loss of life and protect from geological hazards.
City of Wasco	
City of Wasco General Plan (City of Wasco 2010)	Provides objectives and policies related to emergency planning, fire protection, flooding, and public safety. • Chapter 7, Safety Element: Objective 7.1.A and Policy 7.1.2 reduce potential property losses and loss of life as well as having all buildings conform to safety standards.
City of Shafter	
City of Shafter General Plan (City of Shafter 2005)	Provides objectives and policies related to open space, water resources, biological resources, mineral resources, cultural resources, air quality, energy, geology and seismicity, flooding, hazardous materials, and emergency services. • Chapter 6, Mineral Resources: Objective 6.5, Policies 6.5.1 through 6.5.4 protect and provide management for mineral resource areas. • Chapter 7, Geology and Seismicity: Objective 7.2, Policies 7.2.1 through 7.2.8 minimize the damage and loss of life from a geological event.

Table 3.9-1
Local Plans and Policies

Policy Title	Summary
City of Bakersfield	
Metropolitan Bakersfield General Plan (City of Bakersfield and Kern County 2007a, 2007b)	Provides goals, policies, and implementation measures for biological resources, mineral resources, soils and agriculture, water resources, air quality, seismic, flooding, and public safety. • Chapter 5, Conservation Element: Goals B.1 through B.4, Policies B.1 through B.16, and Implementation Measures B.1 through B.5 protect areas of significant resource potential for future use and avoid conflicts between the productive use of mineral and energy resource lands and urban growth. • Chapter 8, Safety Element: Goals A.1 through A.7, Policies A.1 through A.25, and Implementation Measures A.1 through A.36 reduce the level of death, injury, property damage, economic and social dislocation, and disruption of vital services that would result from earthquake damage.

3.9.3 Methods for Evaluating Impacts

The methodology used to describe the affected environment and evaluate the potential environmental impacts of the project on geology, soils, and seismicity involved a review and assessment of published maps, professional publications, and reports pertaining to the geology, soils, and seismicity of the project vicinity. The information included USGS topographic maps; USGS and CGS geologic and landslide maps; Natural Resources Conservation Service (NRCS) soils maps; CGS Seismic Hazard Zone maps; USGS and CGS active fault maps; USGS and CGS ground-shaking maps; California Emergency Management Agency's dam inundation maps, USGS and State of California mineral commodity producer databases; and online databases for mineral resources, fossil fuels, and geothermal resources published by the State of California Department of Conservation, Division of Oil, Gas, and Geothermal Resources (DOGGR).

The analysis included a review of geotechnical data collected for the current conceptual level of design. These data are summarized in the *15% Record Set Fresno to Bakersfield Geologic and Seismic Hazard Report, California High-Speed Train Project Engineering* (Authority and FRA 2013). This report summarizes the geologic setting for the alignments, describes site conditions, and provides preliminary evaluations and recommendations for addressing geologic hazards, natural chemical hazards and corrosion potential, and foundation support methods. The geotechnical information presented in the technical report and used in the analysis in this EIR/EIS included representative boring logs along the alignments, as well as preliminary engineering interpretations. Much of the information on borings had been obtained at stream and river crossings. This report also summarizes the results of geotechnical explorations conducted by Caltrans, and others, along or within the vicinity of the HST alignments. Existing geological and geotechnical information was sufficient to address the potential impacts of the project. Further site-specific geotechnical investigations for the project would be conducted for the final engineering design. This information would be used for detailed design of specific structures and foundations.

The impact analysis evaluates two risks:

- The proposed project's potential to increase the risk of personal injury, loss of life, and damage to property, including planned new facilities, *as a result of* existing geologic, soils, and seismic conditions.
- The potential adverse effects of the project *on* the existing geology, soils, and seismicity; for example, erosion of topsoil.

3.9.3.1 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 are 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 exist, when on balance the impact is negligible or even beneficial.

For project risks from geology, soils, and seismicity, the terms are defined as follows: an impact of *negligible* intensity is defined as an increased risk of personal injury, loss of life, and damage to property related to geology, soils, and seismicity that are slightly greater, but very close to the existing conditions. An impact of *moderate* intensity is defined as a localized increased risk of personal injury, loss of life, and damage to property as a result of existing geologic, soil, or seismic conditions, or localized adverse effects of the project on the existing geology, soils, and seismicity. Effects of *substantial* intensity 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 effects with substantial intensity.

Definitions

Soil Hazards: Soil hazards include characteristics such as liquefaction potential, corrosivity, and shrink swell potential, all of which may require special engineering considerations during design and construction.

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.

Land subsidence: Loss of surface elevation due to removal of subsurface support. A common cause of subsidence in the area has been oil or groundwater withdrawal.

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

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

3.9.3.2 CEQA Significance Criteria

For the purposes of this EIR/EIS, the 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.

3.9.3.3 Study Area for Analysis

The potential area of disturbance associated with the construction of the project includes the proposed HST alignments and associated facilities, as well as the roadway changes necessary to accommodate the HST alignments and temporary construction laydown areas. These are described in Section 3.1, Introduction to Chapter 3, and in more detail in Chapter 2, Alternatives.

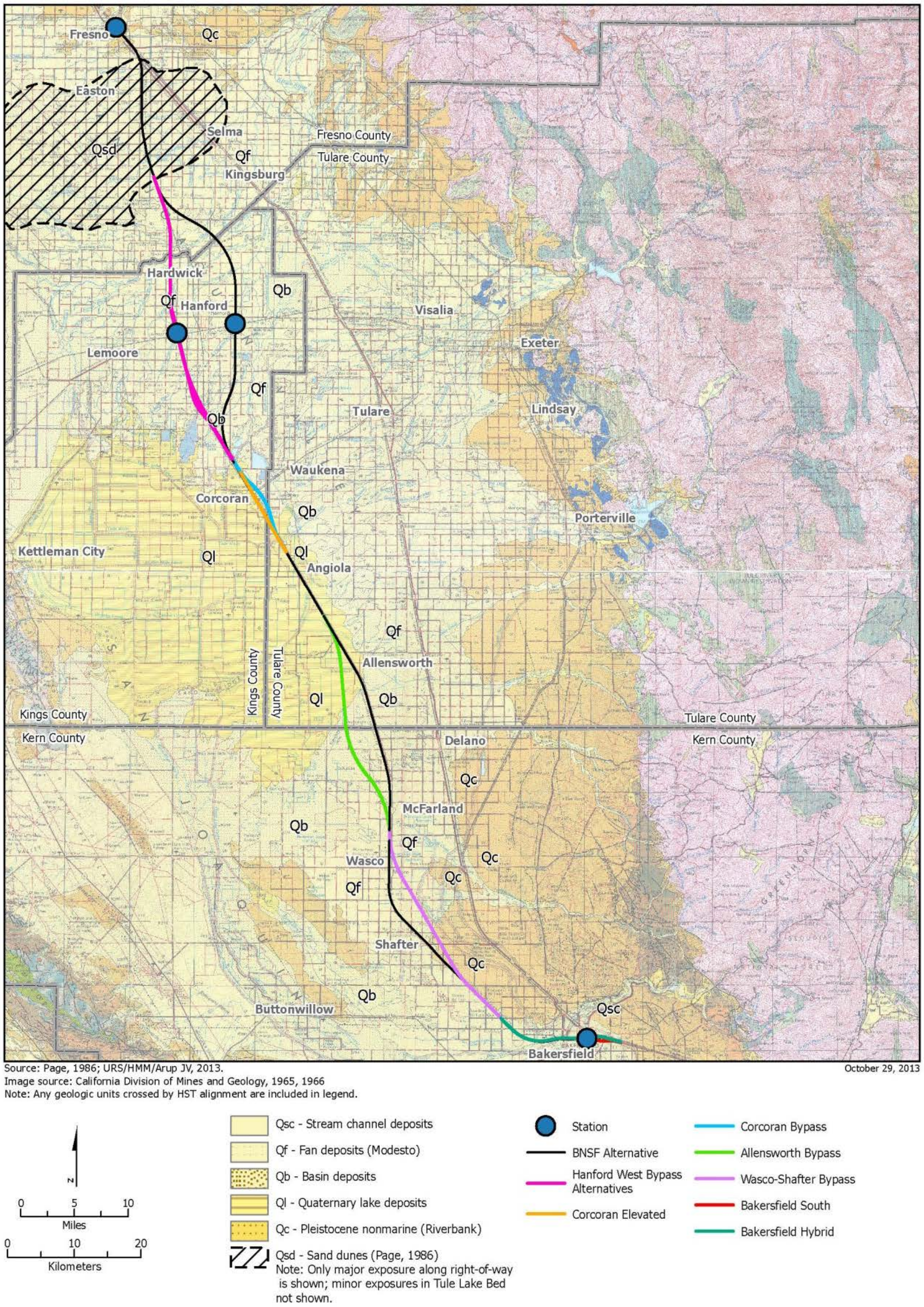
Geologic hazards and seismic hazards, such as soil failures (e.g., adequacy of load-bearing soils), settlement, corrosivity, shrink-swell, erosion, and earthquake-induced liquefaction risks, are direct effects that affect the area immediately adjacent to the HST alignment alternatives. For assessment of these risks, the study area is up to 150 feet on either side of the project alternative footprints. The study area is a 0.5-mile radius for subsurface gas hazards, mineral resources, and oil and gas resources, which expands to 2 miles around the proposed Heavy Maintenance Facility (HMF) 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.

For this discussion, the Fresno to Bakersfield Section is divided into three segments, as shown on Figure 3.9-1, and defined as follows:

- Fresno segment: Begins at approximately Amador Street, continues south through Downtown Fresno, and terminates at East Jefferson Avenue, just south of the Fresno city limits, for a distance of approximately 7 miles.

- Rural segment: Begins at East Jefferson Avenue just south of Fresno and continues southeast to approximately State Route (SR) 58 (Rosedale Highway) on the northern outskirts of Bakersfield, for a distance of approximately 99 miles.

- Bakersfield segment: Begins at SR 58 on the northern outskirts of Bakersfield and continues east through the Bakersfield Station to Oswell Street, a distance of approximately 12 miles.



Source: Page, 1986; URS/HMM/Arup JV, 2013.
Image source: California Division of Mines and Geology, 1965, 1966
Note: Any geologic units crossed by HST alignment are included in legend.

Note: Only major exposure along right-of-way is shown; minor exposures in Tule Lake Bed not shown.

Figure 3.9-1
Surficial geology within the study area

3.9.4 Affected Environment

The affected environment for geology, soils, and seismicity includes the following elements: physiography and regional geologic setting, geology of the proposed HST alternatives, site soils, geologic hazards, primary seismic hazards, secondary seismic hazards, areas of difficult excavation, and mineral and energy resources. There are no applicable regional plans or policies pertaining to geology, soils, and seismicity within the Fresno to Bakersfield Section study area. The defined affected environment is used to describe the context by which the evaluation will be made to determine whether geology, soils, and seismicity impacts are significant under NEPA and CEQA.

3.9.4.1 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, nearly 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 in the north and the San Joaquin Valley in the south.

The Central Valley occupies a structural trough created about 65 million years ago by collision of the Pacific and North American tectonic plates. Sediment from ocean water, river deposition, and glacial deposition filled the trough with an approximately 6-mile-thick layer of continental and marine sediments above rock (Authority and FRA 2004).

The study area is located in the central part of the San Joaquin Valley. The topography in this part of the Central Valley is flat-lying, with elevations across the project alternatives and HMFs ranging between +395 feet (North American Vertical Datum of 1988 [NAVD 88]) to +205 feet (NAVD 88). A general downward gradient occurs in the study area to the west-southwest, determined principally by the gentle slope of the vast alluvial fans extending from the Sierra Nevada in the east to the center of the San Joaquin Valley.

3.9.4.2 Geology Along the Proposed High-Speed Train Alternatives

Geologic formations along the proposed alignments include the Modesto and Riverbank formation. The Modesto and Riverbank formations are similar 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 origin of much of the sediment. Bedrock is about 6 miles below ground surface (bgs).

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 by location. Figure 3.9-1 shows the surficial geology, and Table 3.9-2 provides a summary of information on mapped surficial geology. Table 3.9-3 identifies the predominant geology from north to south within the Fresno to Bakersfield Section.

Table 3.9-2
Summary of Mapped Surficial Geologic Units

Map Symbol	Geologic Formation	Geologic Unit Type	Description
Qsd	Recent sand dunes	Sand dunes	Cross-bedded, well-sorted medium to coarse sand as well as some very fine to fine sand and silt.
Qsc	Stream channel deposits	Alluvial Deposits	Sediments along river channels and major streams; sand, gravel
Qf	Modesto Formation	Recent Alluvial Fan Deposits	Sediments deposited from highlands surrounding the Great Valley composed of granitic sand and silt
Qb	Recent basin deposits	Basin Deposits	Sediments deposited during flood stages of major streams in areas between natural stream levees and fans; silts and clays
Ql	Quaternary lake deposits	Lake Deposits	Clay, silt, and fine sand of lake beds in former Tulare Lake
Qc	Riverbank Formation	Pleistocene Nonmarine Sedimentary Deposits	Older alluvium, slightly consolidated and dissected fan deposits composed of sand, gravel, and cobbles

Sources: CDMG 1965, 1966; Page 1986.

Table 3.9-3
Predominant Geologic Formations between City of Fresno and City of Bakersfield

Location	BNSF Alternative*
Vicinity of Fresno	Recent alluvial fan deposits (Qf-Modesto Formation) and older Pleistocene nonmarine sediments (Qc-Riverbank Formation); clay, silt, and sand with occasional gravel; local artificial fills
South of Fresno to just south of Conejo	Sand dunes (Qsd)
South of Laton to north of Corcoran	Alluvial fan deposits (Qf-Modesto Formation)
Vicinity of Corcoran south to Allensworth	Alluvial fan deposits (Qf-Modesto Formation), clay, silt, and sand, and lake deposits (Ql) consisting of fine sand, silt, and clay
Allensworth to Shafter	Alluvial fan deposits (Qf), clay, silt, and sand, and lake deposits (Ql) consisting of fine sand, silt, and clay, Quaternary basin deposits (Qb)
Shafter to Bakersfield	Alluvial fan deposits (Qf), clay, silt, and sand
Vicinity of Bakersfield	Fan deposits (Qf) and stream channel deposits (Qsc) consisting of clay, silt, sand, and gravel being reworked by the Kern River

Sources: CDMG 1965, 1966; Page 1986.
Notes:
* Geologic formations similar for all alternatives.
Qf (Modesto Formation) and Qc (Riverbank Formation) only identified by formational name on Fresno sheet, not on Bakersfield sheet.

Most of the available geologic and stratigraphic information is, as noted above, from geotechnical investigations at river and stream crossings where bridges have already been constructed. Geotechnical investigations 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 stations and HMFs are competent stiff to hard silts and clays or dense to very dense sands. Competent soils are soils that resist settlement and would not continue to compress when bearing the weight of typical project components. However, some occurrences of fine-grained soil range from soft to medium-stiff in consistency and some cohesionless soils occur, ranging from loose to medium-dense. Generally, these less-competent materials are encountered in the upper 10 to 20 feet. Between 20 and 30 feet, soils are typically more competent, stiff to hard silts and clay and dense sands. Dense sands and hard silts are usually encountered at depths of 30 to 60 feet bgs. Gravels occur in some soil layers.

Depth to groundwater typically ranges from 80 to over 270 feet bgs in the study area, and varies considerably each season, depending on rainfall conditions. In general, groundwater is typically shallower toward the northern end of the BNSF Alternative (Fresno) and deepest at the southern end, in the vicinity of Wasco-Shafter and Bakersfield. Table 3.9-4 provides a summary of groundwater depths at different locations along the alignments. Locally, perched groundwater may be encountered at shallower depths.

Table 3.9-4
Summary of Groundwater Depth at Various Locations

Location	Depth to Groundwater (feet)
Downtown Fresno Station Area	80 to 100
Hanford	100 to 120
Corcoran	110
Wasco	270
Bakersfield	150 to 180

Source: DWR 2005.

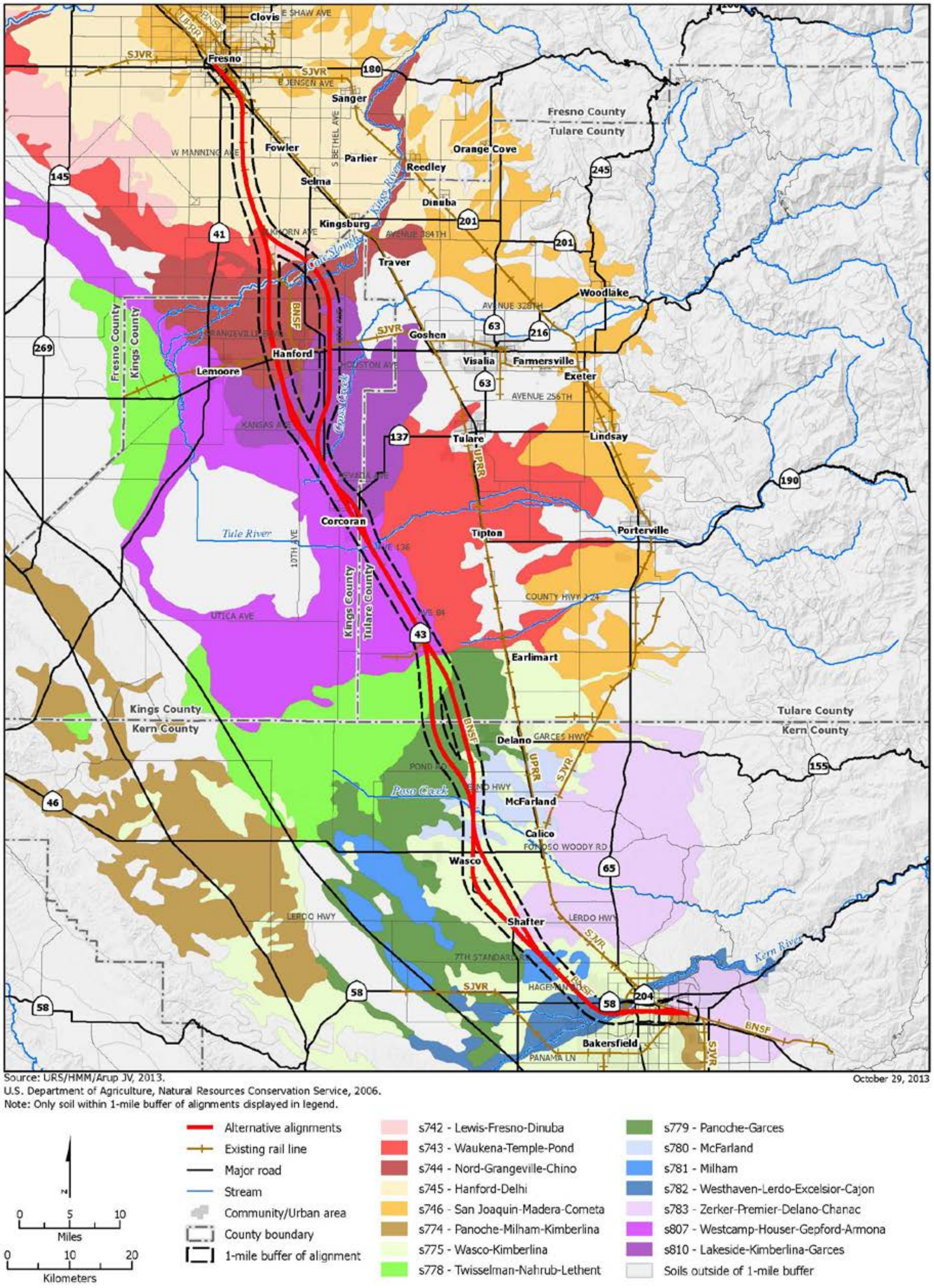
3.9.4.3 Site Soils

NRCS soil surveys describe soils associated with the proposed alternatives, including stations and HMFs (USDA-NRCS 2006). This soils information is based on conditions within the upper 4 to 5 feet of the ground surface. Figure 3.9-2 shows the soil associations in the study area. Table 3.9-5 provides a summary of the physiographic features, soil associations, and counties of occurrence.

The soils within the study area generally occur in one of the four physiographic locations. The characteristics of the physiographic locations and the associated soils are summarized below:

- Alluvial fans and floodplains. These soils are found in Fresno, Kings, Tulare, and Kern counties. Alluvial fans are fan-shaped deposits of water-transported material (alluvium). They typically form at the base of topographic features where there is a marked break in slope. Consequently, alluvial fans tend to be coarse-grained, especially at their mouths where the energy of the stream or river is still high. At their edges, however, where energy levels can be low to quiescent, they can be relatively fine-grained. They are developed in nearly level and gently sloped ground conditions, along drainage ways, on alluvial fans, and on floodplains. Characteristics often vary greatly within short distances because the soils developed within compositionally variable stream deposits. Some areas may have compacted silt or sand or an iron-silica hardpan. Typically, these soils have little clay content, exhibit low to moderate shrink-swell potential, are moderately to highly corrosive to uncoated steel, and are slightly corrosive to concrete. These soils also have slight potential for water and wind erosion. Sand dunes have also been identified in the area south of Fresno (see Figure 3.9-1).

- Low alluvial terraces. These soils are found in Fresno and Kern counties. They are often found in rolling topography, and can include a strongly cemented or indurated hardpan in the subsoil. The hardpan can be composed of cemented silica or clay. These soils contain expansive clays, resulting in moderate to high shrink-swell potential. These soils are highly corrosive to uncoated steel, and moderately corrosive to concrete. They can have a moderate potential for water erosion, and a high potential for wind erosion.
- Basin areas (including saline-alkali basins). These soils are found primarily in Kings, Tulare, and the northern portion of Kern counties. The topography of these areas is nearly level or gently undulating. They have more clay content than fans and terraces, and nearly all have accumulations of salt and alkali due to poor drainage. Most of these soils have cemented lime-silica hardpans in the subsoil. These soils exhibit low to high shrink-swell potential, are highly corrosive to uncoated steel, and are moderately corrosive to concrete. They are also moderately to highly susceptible to water and wind erosion.



Source: URS/HMM/Arup JV, 2013.
U.S. Department of Agriculture, Natural Resources Conservation Service, 2006.
Note: Only soil within 1-mile buffer of alignments displayed in legend.

Figure 3.9-2
Soil associations within the study area

Table 3.9-5
Summary of Soil Associations

Soil Association[a]	Counties of Occurrence	Landform Groups	Potential Soil Hazards Characterization
San Joaquin-Madera-Cometa	Fresno	Low alluvial terraces	None to moderate erosion potential; low to high shrink-swell potential; high corrosivity potential
Hanford-Delhi (also identified as Qsd (sand dunes) on Figure 3.9-1)	Fresno	Young alluvial fans and alluvial benches	None to slight water erosion potential; slight to moderate wind erosion potential; low shrink-swell potential; low corrosivity potential
Waukena-Temple-Pond	Fresno	Basin floodplain	None to slight water erosion potential; slight wind erosion potential; low to moderate shrink-swell potential; low to high corrosivity potential
Lewis-Fresno-Dinuba	Fresno	Alluvial fans and valley plains	None to slight erosion potential; low to moderate shrink-swell potential; high corrosivity potential
Nord-Grangeville-Chino	Fresno/Kings	Lower parts of recent alluvial fans and floodplains	None to slight erosion potential; low to moderate shrink-swell potential; low to high corrosivity potential
Lakeside-Kimberlina-Garces	Kings/Tulare	Alluvial fans	Slight water erosion potential; low to high shrink-swell potential; slight to moderate wind erosion potential
Westcamp-Houser-Gepford-Armona	Kings/Tulare	Low alluvial fans, basins, and floodplains	Slight wind erosion potential, moderate to high water erosion potential; low to high shrink-swell potential; high corrosivity potential
Twisselman-Nahrub-Lethent	Tulare	Basin rims and fan remnants	Moderate to high water erosion potential; moderate wind erosion potential; low to moderate shrink-swell potential; high corrosivity potential
Panoche-Garces	Tulare/Kern	Alluvial fans and floodplains	Slight water erosion potential; slight to moderate wind erosion potential; low to moderate shrink-swell potential
McFarland	Kern	Alluvial fans and floodplains	Slight water erosion potential; low to moderate shrink-swell potential; high corrosion potential to uncoated steel
Wasco-Kimberlina	Kern	Alluvial fans, fan skirts, and plains	Slight water erosion potential; low to moderate shrink-swell potential; low to high corrosivity potential
Zerker-Premier-Delano-Chanac	Kern	Alluvial plains and terraces	Low shrink-swell potential; low wind erosion potential
Milham	Kern	Alluvial fans	Low to moderate erosion potential; low to moderate shrink-swell potential
Westhaven-Lerdo-Excelsior-Cajon	Kern	Alluvial fans and fan skirts	Moderate to high erosion potential; slight wind erosion potential; low shrink-swell potential
Panoche-Milham-Kimberlina	Kern	Alluvial fans, plains, and low terraces	Local moderate water erosion potential; high corrosivity potential to uncoated steel

Source: USDA-NRCS 2006.

[a] As mapped by USDA-NRCS 2006. Refer to Figure 3.9-2 for locations of soil associations.

3.9.4.4 Geologic Hazards

The review of the affected environment considered two types of nonseismic geologic hazards for the project alignments and HMFs: slides or slumps along steep slopes located next to rivers and creeks; and general land subsidence. These geologic hazards pose potential threats to the health and safety of citizens.

- Slides and slumps. Topography along the alignments and at the stations and HMFs is generally very flat, with principal relief occurring where stream channels have been incised into the landscape. Large, deep-seated landslide areas have not been identified during review of available USGS and CGS landslide inventories. A number of streams, creeks, and rivers occur along the alignments, with slopes that vary in height and steepness. Localized, surficial failures of these slopes can occur from changes in groundwater, erosion, changes in slope steepness from construction activities, or new earth loads being placed at the top of the slope. The potential for the slumps and slides increases with slope steepness and height.

- Land subsidence. San Joaquin Valley has a long history of land subsidence in response to water and mineral (oil and gas resources) extraction; in some areas, land subsidence has been close to 30 feet (USGS 2013).

The Fresno to Bakersfield Section transverses or is near areas that are experiencing subsidence. These areas include:

- Kings County: Information on the county's seismic safety map indicates that areas along the HST alternatives near Corcoran have the potential for additional subsidence resulting from liquefaction, which can occur during seismic ground shaking (Kings County Community Development Agency 2010a).

- Tulare County: The Kern County Multi-Hazard Mitigation Plan and USGS subsidence maps show that areas between Wasco and Tulare have experienced significant amounts of subsidence due primarily to groundwater extraction. The area of most recorded subsidence, commonly known as the Tulare-Wasco Subsidence Bowl, occurs in the vicinity of Pixley, approximately 10 miles to the east of the BNSF alignment. Studies using Interferometric Satellite Aperture Radar (InSAR) have detected a 9-mile by 9-mile area to the south of Pixley subsiding at a rate of about 1 inch/year between 1992 and 1995 (Brandt et al. 2005). Assuming that there have been no changes in subsidence rates since the InSAR study, it is anticipated that subsidence rates in the area south of Pixley will be 1 inch/year or less.

- Kern County: Subsidence near the HST alignment in the vicinity of the Kern Lake bed is caused by groundwater overdrafts (when the rate of groundwater extraction exceeds the rate of recharge) in the area of Arvin, to the southeast of Bakersfield. Oil-field related subsidence is also known to occur in small areas south and west of Bakersfield (Kern County Planning Department 2007b).

USGS (2013) assessed land subsidence in the vicinity of the Delta-Mendota Canal as part of an effort to minimize future subsidence-related damage to the canal. Although the USGS study area did not overlap with the study area in this EIR/EIS, the results of their study were consistent with prior evidence indicating land subsidence occurs in the San Joaquin Valley due to groundwater use, particularly during drought conditions when surface water deliveries are reduced.

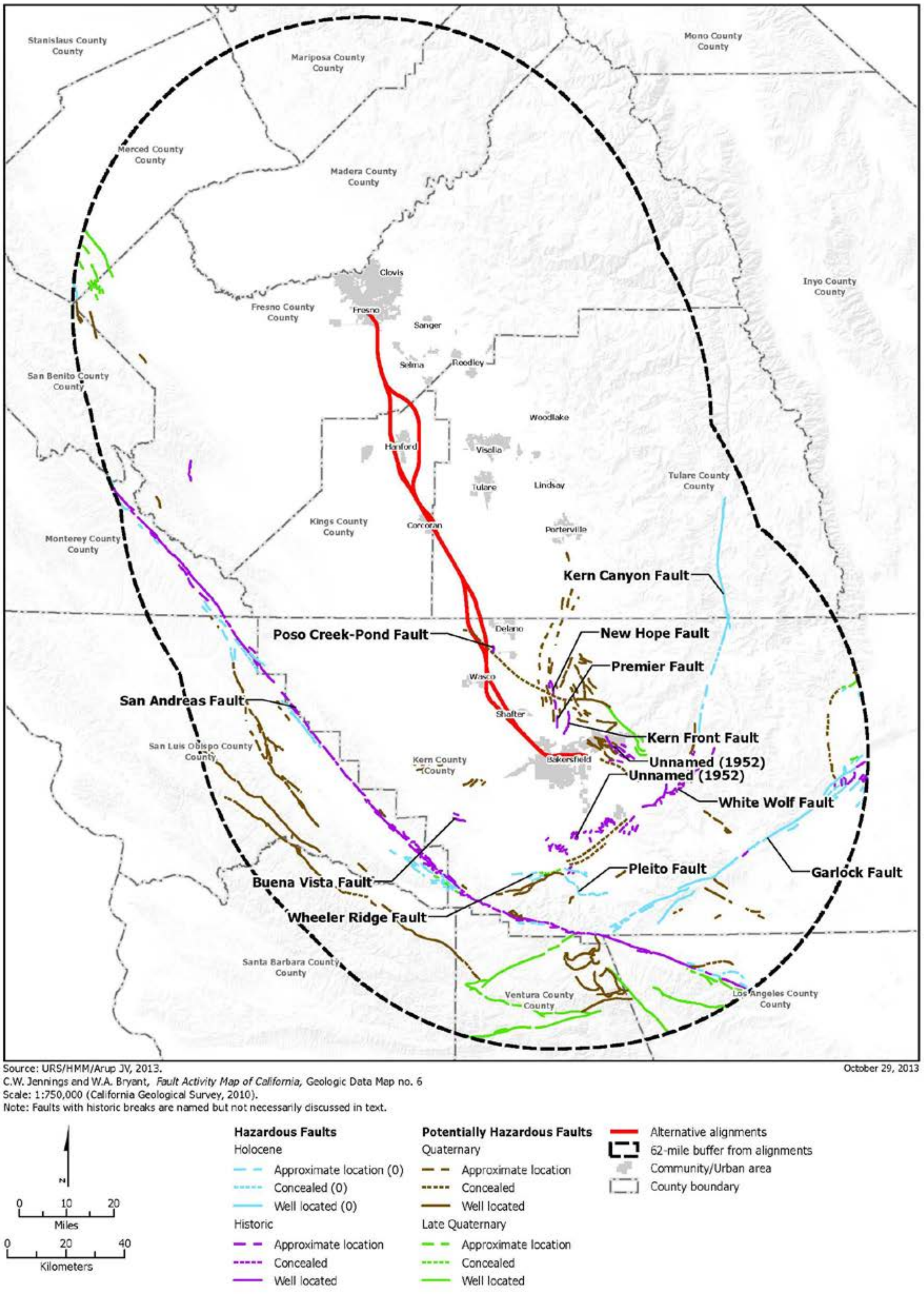
3.9.4.5 Primary Seismic Hazards

The primary seismic hazards assessed for the project alignments are surface fault ruptures transecting the alignment(s), and ground shaking. Both active and inactive faulting is prevalent throughout California. As discussed below, only hazardous and potentially hazardous faults are considered. Figure 3.9-3 shows hazardous and potentially hazardous faults within about 62 miles of the HST alternatives. A seismic event along any of these faults, 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.

A hazardous fault is defined as a ground rupture that has occurred within approximately the last 11,000 years. This includes historic surface ruptures (approximately the last 200 years), as well as older Holocene displacements. A potentially hazardous fault includes ruptures that occurred between 11,000 and 1.6 million years ago. Of the known hazardous fault zones that occur in the project area, those that would pose the greatest hazard to the Fresno to Bakersfield Section are the San Andreas Fault to the west, the Kern Canyon Fault to the east, and the White Wolf and Garlock faults to the south. Figure 3.9-3 depicts a portion of a California fault map. The San Andreas Fault, at its closest, is approximately 70 miles to the west of the Fresno Station and approximately 37 miles to the west of the Bakersfield Station. The northern portion of the Kern Canyon Fault is approximately 60 miles to the east of the BNSF Alternative and runs roughly parallel to the southern portion of the alternatives (Figure 3.9-3). The White Wolf Fault and Garlock Fault are approximately 18 miles and 35 miles, respectively, to the southeast of the proposed Bakersfield Station. These faults and the available data pertaining to them indicate that they could be the source of strong ground shaking for the four-county study area included in the 62-mile radius.

Definition

A *fault zone* is 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.



Source: URS/HMM/Arup JV, 2013.
C.W. Jennings and W.A. Bryant, *Fault Activity Map of California*, Geologic Data Map no. 6
Scale: 1:750,000 (California Geological Survey, 2010).
Note: Faults with historic breaks are named but not necessarily discussed in text.

Figure 3.9-3
Hazardous and potentially hazardous faults within 62 miles of the HST alternatives

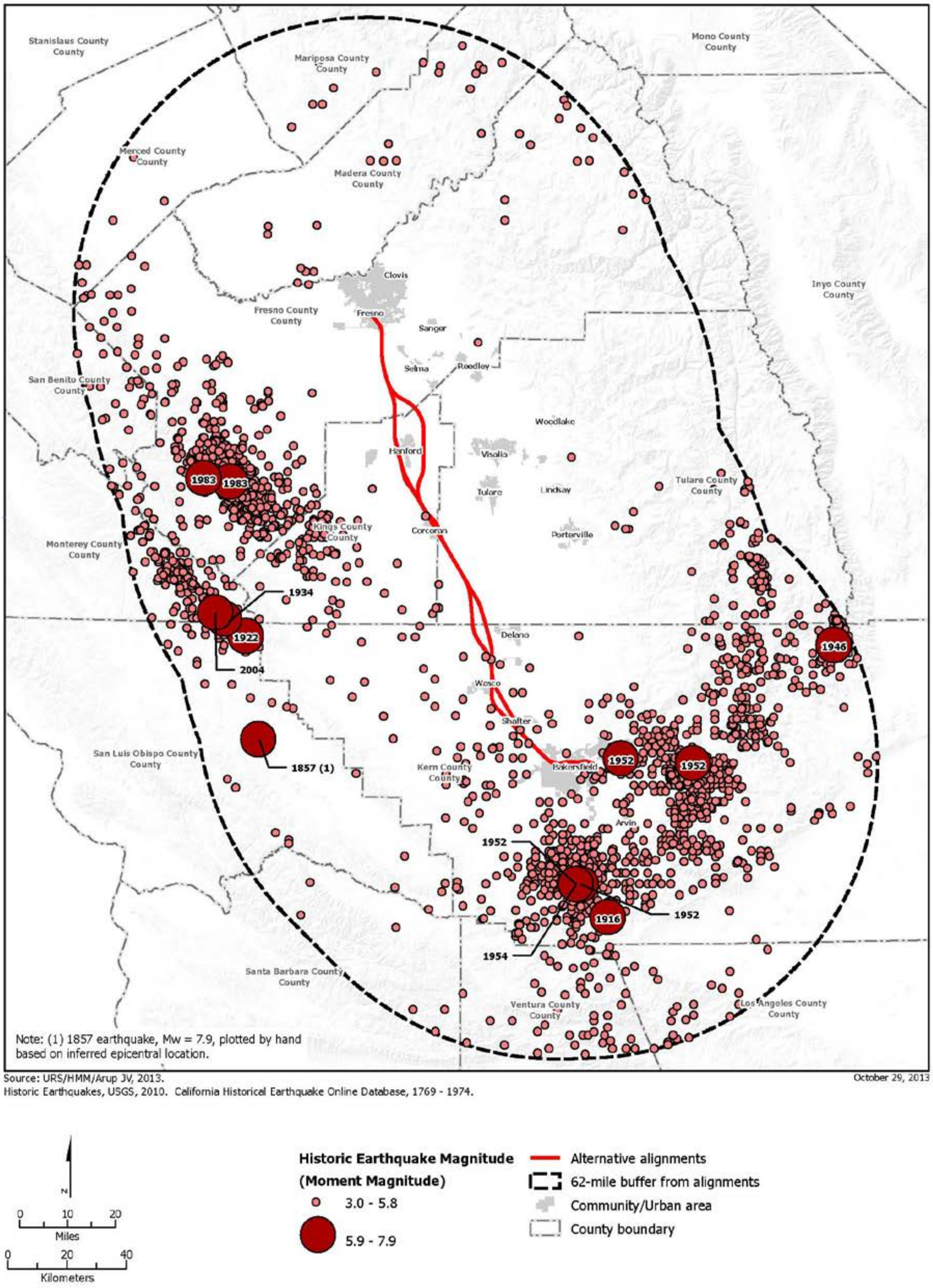
The review of information published by the USGS and CGS determined the following primary seismic hazards for the project:

- Surface Fault Rupture. Fault rupture refers to the extension of a fault to the ground surface, which causes the ground to break, resulting in an abrupt, relative ground displacement. Surface fault ruptures are the result of stresses relieved during an earthquake event and often cause damage to structures astride the rupture zone. However, within the study area there are several faults including the Premier, New Hope and Poso Creek-Pond (Smith 1983) (Figure 3.9-3) that have experienced surface rupture associated with fluid extraction. The only mapped fault that crosses the project alignment is the Poso Creek-Pond Fault; there is no evidence to suggest that this fault has experienced Holocene surface rupture. The Poso-Creek-Pond Fault is in Kern County, trending north-south east of Pond, California (Figure 3.9-3). The fault consists of a 0.67-mile-wide zone of northwesterly trending normal faults (Los Angeles Department of Water and Power 1974). The BNSF Alternative crosses the concealed portion (no surface expression) of the Poso Creek-Pond Fault approximately 1.2 miles south of the intersection of Pond Road and SR 43. The Allensworth Bypass Alternative crosses the concealed portion of the Poso Creek-Pond Fault approximately 2.6 miles east of the intersection of Woollomes Road and SR 43. This fault dates to the Quaternary Period (less than 2,600,000 years before the present), or older. No evidence of surface rupture is associated with Poso Creek-Pond Fault. While evidence of surface rupture appears along areas of the Pond Fault (e.g., cracked pavement and dips in nearby highways), surface rupture due to faulting is unlikely at the HST alignments, because the nearest surficial expressions of the fault are located more than 1.6 miles to the east.

- Ground Shaking. The study area for the Fresno to Bakersfield Section is susceptible to strong ground shaking generated during earthquakes on nearby faults. Strong ground motion occurs as energy is released during an earthquake. The intensity of the ground motion depends on the distance to the fault rupture, the earthquake’s magnitude, and the geologic conditions underlying and surrounding the site through which the seismic waves pass. The ground motions induced by a seismic event are characterized by a horizontal peak ground acceleration (PGA) value that is expressed as a percentage of the acceleration of gravity (g). The CGS, in cooperation with the USGS, has developed a probabilistic seismic hazard model for California. Probabilistic estimates of ground motion that correspond to a 2% probability of exceedance in 50 years (2,475-year return period) can be obtained from a USGS website by inputting the latitude and longitude of the project site (USGS 2008). Historic earthquake activity in the region is shown on Figure 3.9-4 (does not include the Fort Tejon-1857 event because of the area shown). Figure 3.9-5 presents the calculated PGA values for the Fresno to Bakersfield Section. PGAs are estimated to range from about 0.24g at the Fresno Station, and generally increase southward to a maximum of about 0.41g at the Bakersfield Station.

3.9.4.6 Secondary Seismic Hazards

A number of secondary seismic hazards could occur in the study area if there were strong ground shaking at the site. The strong ground shaking could result from either a nearby or distant earthquake, depending on the earthquake’s magnitude, depth, and its distance from the project. These secondary hazards include liquefaction, seismically induced slides or slumps, and floods resulting from seismically induced dam failure. The first two of these hazards occur primarily either where liquefiable soils exist or where steep slopes occur within the alternatives or HMFs. In contrast, the seismically induced floods could occur if any one of several dams located in the region fails, releasing impounded water that could eventually inundate the area.



Note: (1) 1857 earthquake, Mw = 7.9, plotted by hand based on inferred epicentral location.

Source: URS/HMM/Arup JV, 2013.
Historic Earthquakes, USGS, 2010. California Historical Earthquake Online Database, 1769 - 1974.

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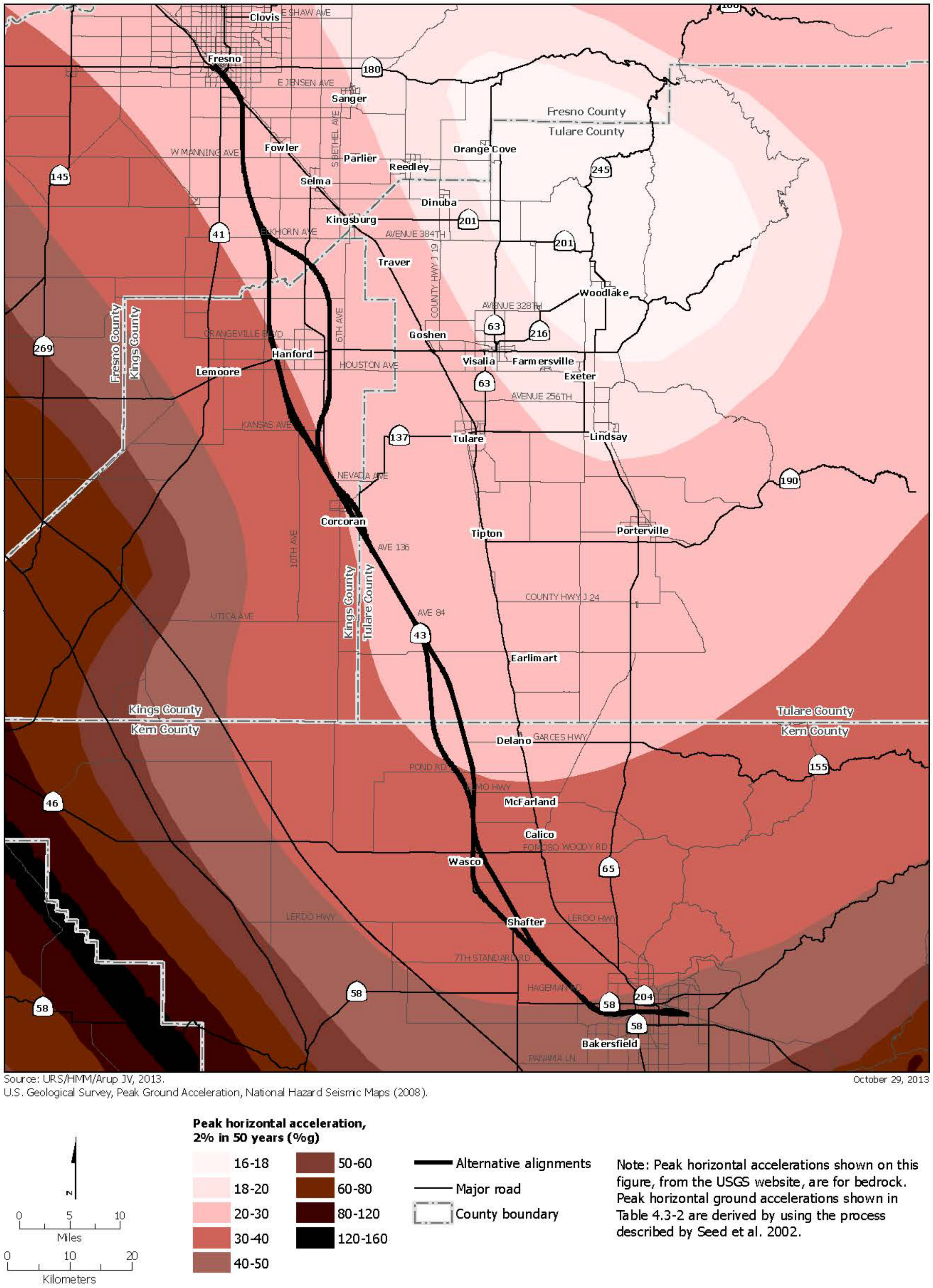
Figure 3.9-4
Historic earthquakes and magnitudes within 62 miles of the HST alternatives



Source: URS/HMM/Arup JV, 2013.
U.S. Geological Survey, Peak Ground Acceleration, National Hazard Seismic Maps (2008).

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Note: Peak horizontal accelerations shown on this figure, from the USGS website, are for bedrock. Peak horizontal ground accelerations shown in Table 4.3-2 are derived by using the process described by Seed et al. 2002.

Figure 3.9-5

Calculated peak ground acceleration (2% probability of exceedance in 50 years)

A potential for liquefaction exists where there are loose, cohesionless soils close to the ground surface (i.e., in the upper 50 feet) and where these soils are saturated (i.e., below static groundwater level). In general, groundwater is located below 50 feet, as summarized in Table 3.9-4. Exceptions may occur where groundwater is within 50 feet of the ground surface; for example, in areas where the HST alignments cross stream and/or river channels or in areas west of Corcoran in the historic Tulare lakebed. At these locations, the potential for liquefaction exists if saturated near-surface soils are loose, cohesionless soils. The combination of groundwater conditions and soil types in combination with estimated PGA of 0.41g is sufficient to warrant further detailed subsurface geotechnical investigations and geotechnical design evaluations in these areas to aid in final site-specific engineering design.

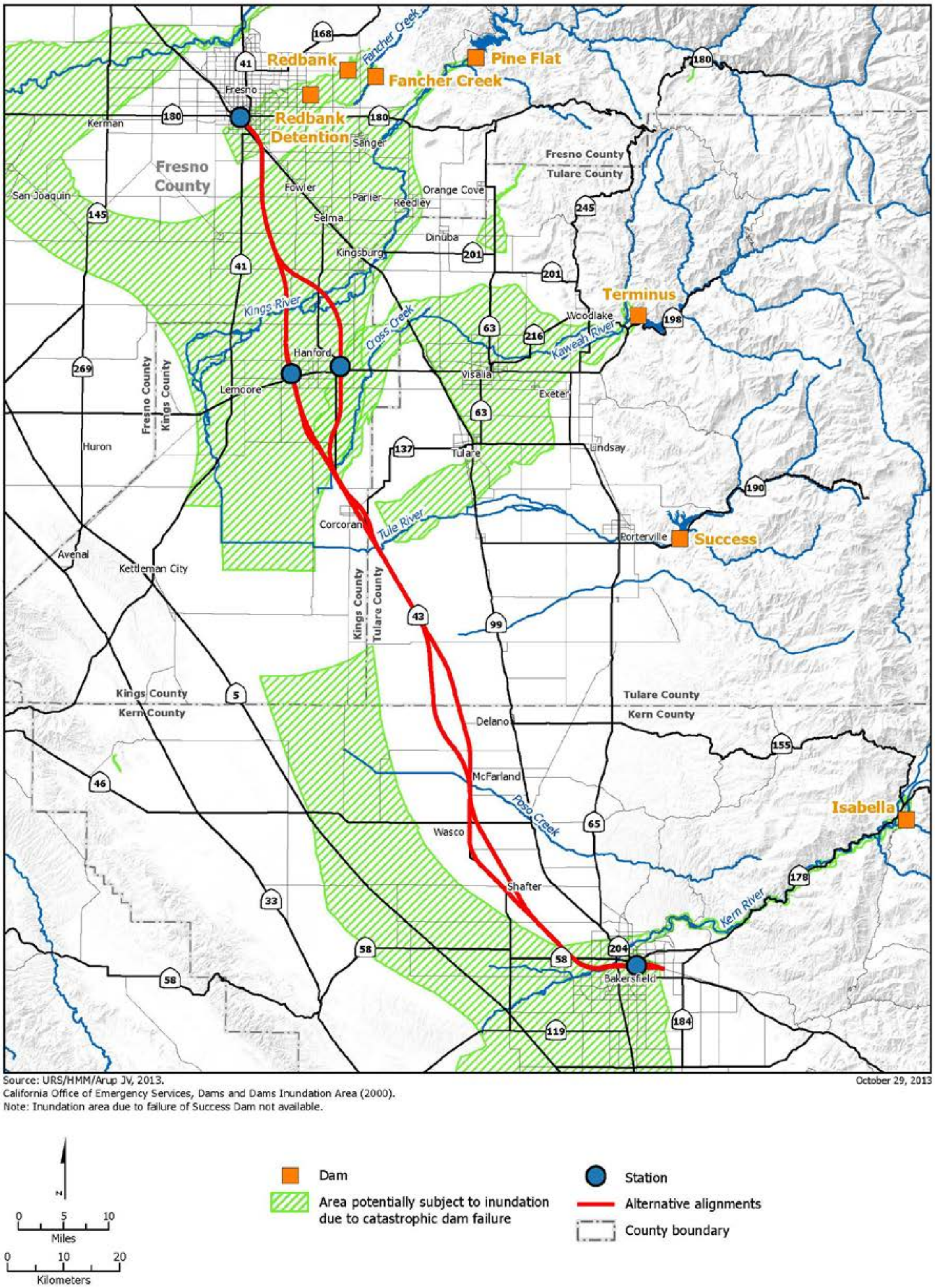
The two primary consequences of liquefaction are loss in soil strength during and after ground shaking, and ensuing subsidence; e.g., ground settlement. The severity of this occurrence depends on the relative density, grain-size characteristics, thickness of the liquefied stratum, and magnitude of the causative seismic event. Where liquefaction occurs at stream and river crossings, the potential also exists for liquefaction-induced lateral spreading or flow of the soil. These liquefaction-related ground displacements could occur on ground that has slope angles of 5 degrees or more. Waterway crossings are the most susceptible locations for liquefaction-induced lateral spreading or flow failures. Consistent with standard industry practice, further detailed subsurface geotechnical investigations and geotechnical design evaluations would be conducted during the later stages of engineering design to confirm any site-specific risks, and to minimize this risk in the final design of structures. These studies would be conducted once the specific alignment has been chosen.

The inertial effects of ground shaking can also be sufficient to cause slopes to fail, even where liquefaction does not occur. In this case, inertial forces in combination with gravity loads exceed the strength of the soil; that is, destabilizing forces exceed the soil's resistance. When this occurs, slope movements can result, and depending on the magnitude of movement, failure can ensue. This hazard is most critical where slopes are steep (e.g., greater than 2H:1V [horizontal to vertical]), 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 inertial effects failures.

The last type of secondary hazard involves water inundation resulting from the failure of dams located to the east of the project. Review of the California Emergency Management Agency's dam inundation maps shows that the Fresno to Bakersfield Section crosses the potential inundation areas of several reservoirs (California Office of Emergency Services 2000), including the small reservoirs on Redbank Creek and Fancher Creek, which are owned by the Fresno Flood Control District. The section also crosses the inundation areas of some larger dams, including Terminus, Pine Flat, Success, and Lake Isabella dams, which are owned and operated by the U.S. Army Corps of Engineers (USACE). Figure 3.9-6 shows the inundation areas relative to the HST alignment alternatives. The inundation areas shown represent conservative scenarios that are based on two key assumptions:

- Seismic shaking associated with the seismic event causes catastrophic failure of the dam/ retaining structures.
- Retained waters are at their maximum operating elevation at the time of the seismic event.

Under these conditions, floodwater depths in areas in the northern and southern portions of the segment could overtop the rails in some areas in the unlikely event of a dam failure.



Source: URS/HMM/Arup JV, 2013.
California Office of Emergency Services, Dams and Dams Inundation Area (2000).
Note: Inundation area due to failure of Success Dam not available.

Figure 3.9-6
Inundation in the study area due to catastrophic dam failures

3.9.4.7 Areas of Difficult Excavation

For these discussions, difficult excavation is defined as excavation methods requiring more than standard earth-moving equipment or special controls to enable the work to proceed. Areas of difficult excavation are most common in bedrock formations, and possibly cemented or hardpan strata not amenable to excavation with a ripper-equipped dozer. Bedrock is generally miles below the ground surface in the Fresno to Bakersfield Section. Cemented zones and hardpan layers, however, are known to occur in and along the project alignments; these zones can be rock-like in consistency. Cemented zones and hardpan form as a result of the soil-weathering process and are found in the subsoil in most of the surficial site soils previously described. These zones can be very difficult to excavate with conventional machinery, depending on the hardpan’s or cemented layer’s thickness and degree of cementation. Areas of difficult excavation along the project alignments (including drilled piers or piles) are not expected to be pervasive because of the predominantly uncemented Quaternary sediments in the San Joaquin Valley, although some localized areas may occur. 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.

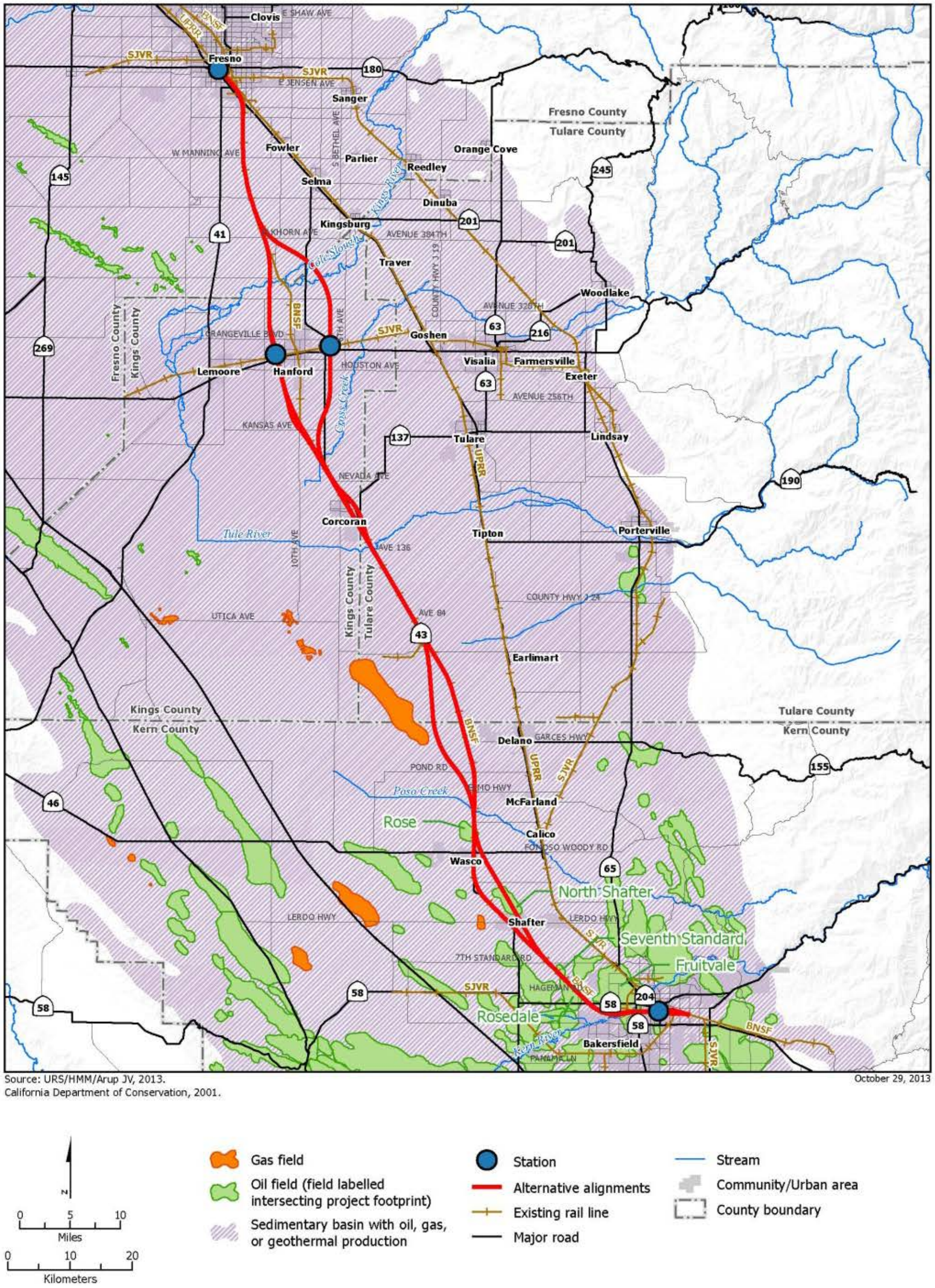
It is possible the combinations of soil conditions and shallow groundwater locations would result in difficult excavation conditions if sufficient consideration is not given to specific conditions when excavating below-grade sections of the track. Any time excavations extend below groundwater levels, a need exists to prevent excess hydrostatic pressures. These conditions are most critical where loose, cohesionless deposits have to be excavated in areas of high groundwater. Although these conditions are unlikely to be encountered on a widespread basis, localized areas where groundwater is near the surface and loose soil conditions exist cannot be ruled out, especially near stream crossings. Areas where difficult excavations may occur are along the BNSF alignment just north of Cole Slough in southern Fresno County and along the BNSF alignment and Allensworth Bypass alignment in southern Tulare County. Perched groundwater conditions may exist in the Hanford area, resulting in in saturated soils from 15 to 80 feet below-grade, making excavation difficult in this area (Authority and FRA 2011b). Further site-specific subsurface geotechnical investigations and geotechnical design evaluations would be conducted during the design of the project to determine specific locations where difficult excavations may occur and to plan for this during construction.

3.9.4.8 Mineral and Energy Resources

Active mining operations in the San Joaquin Valley region are for building materials or aggregate (near-surface sand and gravel) and industrial minerals such as lime, pumice, and gypsum. Aggregate resources are the only mineral resources within the immediate study area. Two active aggregate producers are located within a 2-mile radius of the Downtown Fresno Station: Builders Concrete Inc., and Pacific Cement and Aggregate. Both produce construction-grade sand and gravel.

The Fresno to Bakersfield Section is close to numerous active and abandoned oil and gas fields, as shown on Figure 3.9-7. These fields are primarily in the northern and southern portion of the rural segment of the study area, but some are along the Bakersfield segment. The California HST right-of-way footprint is in the proximity of 22 oil and gas fields between Fresno and Bakersfield, including four abandoned fields. However, only fields actually crossed by the alignment are identified by name on Figure 3.9-7.

The BNSF Alternative crosses the Fruitvale Oil Field approximately 1.5 miles to the west of Bakersfield, the Rosedale Oil Field approximately 6 miles to the west of Bakersfield, the Seventh Standard Oil Field between Bakersfield and Shafter, and the Rose Oil Field near Wasco.



Source: URS/HMM/Arup JV, 2013.
California Department of Conservation, 2001.

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🟧	Gas field
🟩	Oil field (field labelled intersecting project footprint)
▨	Sedimentary basin with oil, gas, or geothermal production
●	Station
—	Alternative alignments
+	Existing rail line
—	Major road
—	Stream
▩	Community/Urban area
⬚	County boundary

Figure 3.9-7
Oil, gas, and geothermal fields in the Fresno to Bakersfield Section

The Wasco-Shafter Bypass passes through the North Shafter Oil Field.

DOGGR jurisdiction includes wells and other ancillary, attendant facilities that have been developed. These ancillary facilities include subsurface fluid flow-and-gathering lines and water injection lines, storage and shipping tanks, gas-oil-water separation units, and other closely related infrastructure facilities.

A review of the DOGGR California Geothermal Map (DOGGR 2001) and the CDMG Geothermal Resources Map (CDMG 1980) indicates that none of the alternative alignments is in or near a Geothermal Resource area, as classified by DOGGR. Also, no known producing or abandoned geothermal wells or geothermal springs are present along the HST alternative alignments.

3.9.4.9 Affected Environment By HST Alternative

The affected environments for the HST alternatives and for the potential HMF locations are generally very similar in the Fresno to Bakersfield 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 alignments and at the alternative HMF sites. These similar conditions also have led to generally similar sets of geologic hazards for the HST alternatives and the alternative HMF sites.

Mapping shown in the Fresno to Bakersfield Section: Geology, Soils, and Seismicity Technical Report (Authority and FRA 2012) suggests that the HST alternative alignments from just north of Cross Creek south through Kings County and most of Tulare County would be located in soils that would be of high corrosivity to concrete while the remainder of the alignments would be located on soils of low to moderate corrosivity to concrete. The HST alternative alignments from Fresno to just north of Conejo would be located on soils predominantly of moderate corrosivity to uncoated steel while the remainder of the alignments would be located on soils of high corrosivity to uncoated steel. Highly erodible soils occur intermittently along the HST alternative alignments from Fresno to Bakersfield. Areas of potential peak ground acceleration generally increase from north to south throughout the project area (see Figure 3.9-5).

HMF alternatives located in the southern portion of the project area (Kern Council of Governments–Wasco HMF, Kern Council of Governments–Shafter East HMF, and Kern Council of Governments–Shafter West HMF) would be located in soils that would be of low corrosivity to concrete compare with moderate levels of corrosivity to concrete for the HMFs to the north (Fresno Works–Fresno HMF, Kings County–Hanford HMF). The Fresno Works–Fresno HMF would be located in an area with moderate corrosivity to uncoated steel, whereas all of the other alternatives would be in areas with soils of high corrosivity to uncoated steel. The Kings County–Hanford HMF would be located in area with highly erodible soils compared to the other alternatives.

The Kern Council of Governments–Wasco HMF, Kern Council of Governments–Shafter East HMF, and Kern Council of Governments–Shafter West HMF are located in a zone of higher peak ground acceleration than HMF's to the north (see Figure 3.9-5).

3.9.5 Environmental Consequences

3.9.5.1 Overview

Geologic, soil, and seismic conditions are similar for all HST alternatives, including the alignment alternatives, stations, and HMF sites. Risks can be addressed with 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 3.9.6, Project Design Features, and as further described in Appendix 2-D.

Geologic risks that should be considered during design and construction include unstable soils and settlement, which presents a low risk to existing infrastructure with incorporation of standard engineering design features. The existing infrastructure includes existing roadways, bridges, buildings, and residential structures. The risk is also low to new HST facilities, such as elevated, retained-fill, at-grade, and retained-cut segments of the alignments, with incorporation of standard engineering design features. The severity of these risks is limited because the geology along the alignment alternatives, stations, and HMF sites is generally very competent, with only localized areas of potentially loose or compressible soils. Where geologic hazards exist, well-proven methods to address these hazards are outlined in standard guidance and engineering standards. For example, wind and water erosion of stockpiled soil would be addressed by implementing provisions in the *Construction Site Best Management Practice (BMP) Field Manual and Troubleshooting Guide* (Caltrans 2003a). With the incorporation of the appropriate construction BMPs and standard engineering design measures, risks to the alignment alternatives, stations, and HMFs from unstable soils, settlement, and erosion are considered to be effects with negligible intensity under NEPA, and would be less than significant impacts under CEQA.

Potential operational impacts for each alignment alternative, station, and HMF 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. The engineering design would incorporate guidelines issued by AASHTO, AREMA, Caltrans, and IBC. With proper incorporation of these guidelines, the severity of these impacts to elevated, retained-fill, at-grade, and retained-cut segments of the alignment would be limited. Collectively, these design measures would reduce the intensity of effects on public health from geologic hazards to negligible under NEPA, and to a less-than-significant impact under CEQA.

3.9.5.2 No Project Alternative

As discussed in Chapter 1, Purpose, Need, and Objectives of the Project, and Section 3.18, Regional Growth, the population in the San Joaquin Valley has been and is projected to continue growing. To accommodate this growth, farmland has been and likely will continue to be converted to other uses, such as residential developments, small business, light-industrial development, and transportation infrastructure. Sections 3.2, Transportation, and 3.19, Cumulative Impacts, list foreseeable future transportation and development projects, which include expansion of SR 99, shopping centers, and large residential developments. Plans for expanding SR 99 include full-access interchanges and additional auxiliary lanes slated for completion by 2020 between Fresno and Bakersfield. These projects are planned or approved to accommodate the projected growth for the Central Valley area.

Infrastructure and development projects carry risks to public safety and create the potential for property damage caused by geology, soils, and seismicity. Risks to infrastructure and developments include localized deposits of soils that have low-bearing capacity 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 infrastructure and development projects would, at a minimum, be subject to the Title 24 Building Code requirements, which require application of engineering design features to address and minimize these risks.

Conversely, infrastructure and development projects could affect geology and soils. Changes in local conditions from project implementation include water or wind erosion, loss of valuable topsoil, or constraints on the potential for oil and gas resource development. Infrastructure and development projects would not affect seismicity. The increasing population would 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 could, if such buildings are not upgraded to current standards, present a risk during a seismic event.

As discussed in Section 3.13, Station Planning, Land Use, and Development, development projects under the No Project Alternative are anticipated to occur at the edge of currently developed areas, rather than in already developed areas, and would thus expand the area in which impacts such as erosion would occur from increased amounts of water runoff.

3.9.5.3 High-Speed Train Alternatives

Construction Period Impacts

Common Soils-Related Impacts

Because of the flat topography, competent soils, and groundwater generally at depths of 50 feet or more, only a limited number of environmental consequences relative to geology, soils, and seismicity are possible during construction. The risk areas are generally located near streams and river crossings where soils tend to be softer and groundwater is often closer to the ground surface or in areas with perched groundwater conditions where groundwater is nearer to the ground surface such as might occur in the Hanford area or west of Corcoran. Table 3.8-11 in Section 3.8, Hydrology and Water Resources, quantifies the number of stream crossings for each alternative. The potential impacts to construction relative to geology, soils, and seismicity include localized deposits of low-strength soils (unstable soils), areas with potential for ground settlement, and soil erosion.

Impact GSS #1 – Encountering Unstable Soils During Construction

Unstable soils consist of loose or soft deposits of sands, silts, and clays that are not adequate to support the planned structure loads. These soils exhibit low shear strength and, when loaded, can fail through bearing failures or slope instabilities. Although the alternative alignments, stations, and HMF sites appear to be dominated by 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 in Section 3.8, Hydrology and Water Resources, for each HST alternative and the HMF alternatives.

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. These potential slumps and slope failures could endanger people or onsite or offsite properties if not addressed. 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 comparatively short duration of construction relative to the frequency of large earthquakes. If an earthquake were to occur during construction, potential effects could range from no effect, to the potential for partially built structures or slopes to fail. This would be very dependent on the size of an earthquake and the specific state of construction of various features at the moment an earthquake occurred. With implementation of appropriate design standards such as Section 1805.3 of the IBC, in addition to standard safety practices during construction, these risks would have negligible intensity under NEPA and a less than significant impact under CEQA.

Construction impacts associated with unstable soils would be the same for all alternative alignments, station alternatives, and potential HMF sites. The project would minimize impacts from potentially unstable soils through foundation design for site-specific conditions, such as the use of deep foundations (e.g., piles) based on site-specific geotechnical investigations (for examples, see Section 1802 of the IBC).

Impact GSS #2 – Soil Settlement at Structures or along Trackway During Construction

Soil settlement could occur during project construction if imposed loads cause compression of the underlying materials. It is a time-dependent process, and is most problematic at locations where soft deposits exist, such as silty or clay soils that have not previously been consolidated by loads of the same levels as would be imposed by new construction. Such loads would be experienced at approach fills for elevated guideways or from embankments constructed to support track structural sections; for example, ballast and sub-ballast, placed to meet track grade requirements.

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. Geotechnical explorations to be undertaken prior to final design and prior to construction would identify the locations with the potential for settlement. In such locations, where subsurface conditions may not be capable of supporting the additional loading induced by additional fill, engineering design features that address soft deposits of silty or clay soils would be incorporated, such as preloading to accelerate settlement or adding wick drains if applicable. Application of the engineering design features would reduce the potential for soil settlement to an effect with negligible intensity under NEPA, and to a less-than-significant impact under CEQA.

In some locations, settlement associated with project construction could also affect nearby existing structures or buried utilities located close to the area of construction. This impact would result from either new structures or earth fills (including retained fills) placed in areas 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. Manuals, such as the *Field Guide to Construction Dewatering* (Caltrans 2001), describe BMPs that can be used to mitigate this type of hazard. The project would implement standard construction and engineering design standards and practices, such as the localized use of well points for dewatering or sheet piling to preclude lowering the groundwater table in sensitive areas, and thus the potential for the HST improvements affecting existing structures or utilities would have negligible intensity under NEPA, and would be less than significant under CEQA.

The city of Fresno reportedly contains tunnels, which were allegedly constructed by Chinese immigrants, in the vicinity of the Fresno station alternatives (USA Today 2007). Recent studies however have failed to produce evidence of true tunnels in the area, although the features may be expansive, partitioned basements (see Section 3.17). Further investigations of these features are ongoing. Following cultural resources evaluation of any discovered features, appropriate foundation design measures would be implemented so that subsurface features would not constitute a hazard to the HST alignment and station construction.

Impact GSS #3 – Soil Erosion During Construction

Accelerated soil erosion, including loss of topsoil, could occur as a result of construction of the project. Soils that have a high potential for wind or water erosion were identified for all alternative alignments, stations, and HMF sites (see Section 3.9.4, Affected Environment). Areas with high potential for soil erosion have been identified north of Laton, in the vicinity of Hanford, north of Corcoran, east of Alpaugh, west of Delano, and in the southeastern portion of Bakersfield, as shown on Figure 3.9-8. With the development of any alternative, the potential for more surface water runoff exists during construction when existing vegetation is removed and the unprotected soils are more exposed to both wind and water erosion. Increased 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 when work areas are cleared of vegetation and materials stockpiled, both the exposed work area and any stockpiles could erode and cause indirect impacts on air and water quality. The potential for erosion from water increases slightly from west to east. Standard construction practices, such as those listed in the *Caltrans Construction Site Best Management Practices (BMPs) Manual* (Caltrans 2003b) and the *Construction Site Best Management Practice (BMP) Field Manual and Troubleshooting Guide* (Caltrans 2003a) will be implemented to reduce the potential for erosion. These could include soil stabilization, watering for dust control, perimeter silt fences, and sediment basins. Because these standard practices would be implemented, effects under NEPA would have negligible intensity and impacts under CEQA would be less than significant.

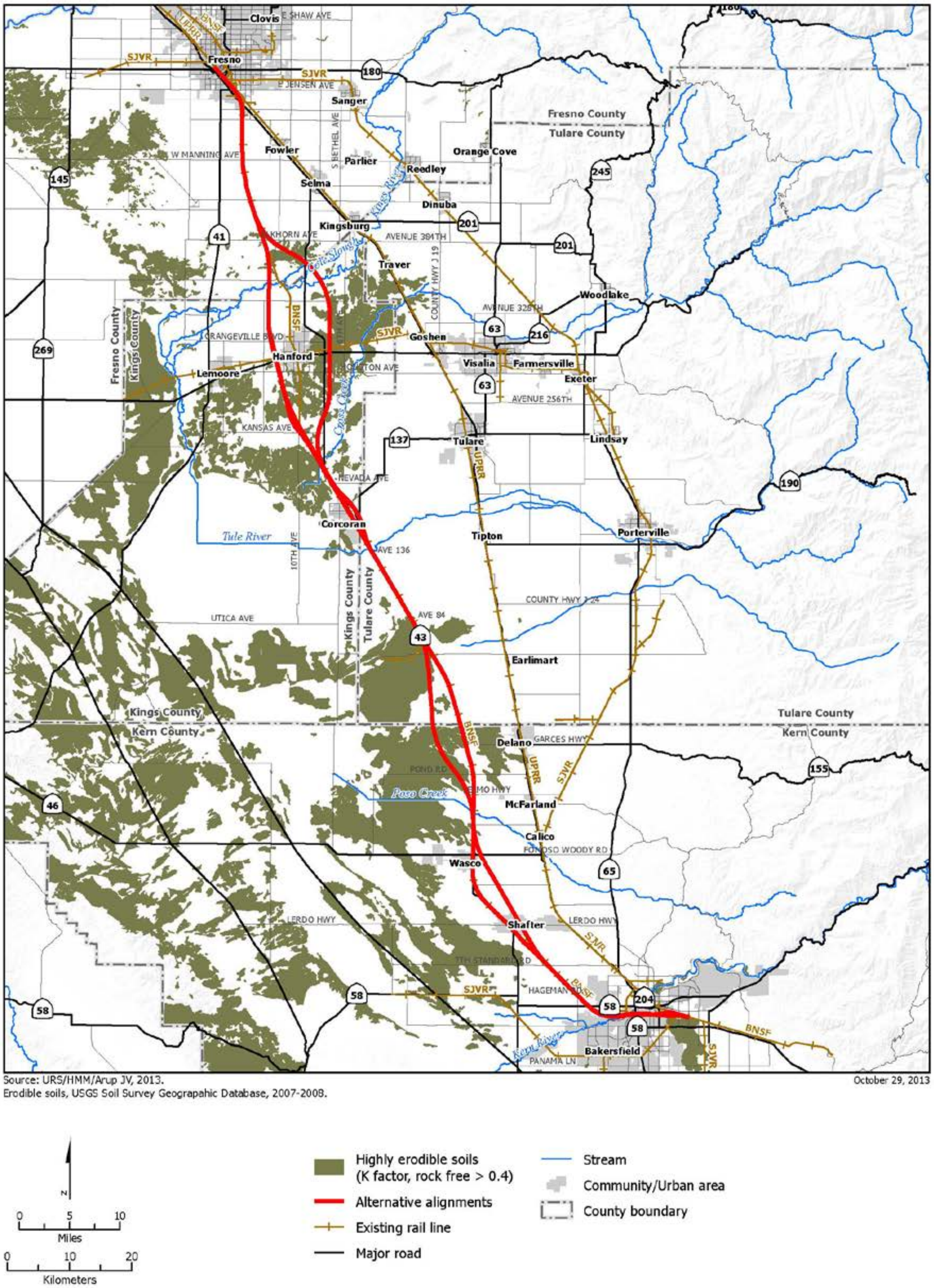
Impact GSS #4 – Difficult Excavations due to Hardpan and Shallow Groundwater

Upper layers of soil can contain cemented zones and hardpan that can be very difficult to excavate with conventional machinery. Excavations in these types of soils are relatively common, 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. These types of design issues are routinely handled during construction through the use of construction dewatering with deep groundwater wells and well points that lower the water level; by use of sheet pile walls systems to stabilize the soil; or by using techniques such as jet grouting and cement deep soil mixing techniques that add cement to the soil, thereby providing a cement-soil mix that resists hydrostatic forces. Alternatively, excavations can be avoided by using deep foundations that can be driven or drilled into the loose, water-saturated soil.

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 a limited need to excavate the hardpan or work below the groundwater level, and deep foundations for elevated structures are conventionally constructed into rock and below the groundwater.

Methods in the *Caltrans Construction Site Best Management Practices (BMPs) Manual* (Caltrans 2003b) and the *Construction Site Best Management Practice (BMP) Field Manual and Troubleshooting Guide* (Caltrans 2003a), such as pre-drilling using rock bits for drilled piers/piles or the use of backhoe-mounted hydraulic impact hammers for shallow excavations, would be used. This would result in effects with negligible intensity under NEPA and less than significant impacts under CEQA.



Source: URS/HMM/Arup JV, 2013.
Erodible soils, USGS Soil Survey Geographic Database, 2007-2008.

October 29, 2013

Figure 3.9-8
Erodible soils in the study area

Impact GSS #5 – Encountering Mineral and Energy Resources During Construction and Loss of Availability of Known Mineral or Energy Resources of Statewide or Regional Significance

Aggregate resources are the only mineral resources within the study area. Although aggregate mining occurs in the study area near Fresno, no mineral resources are known to exist within the footprint of the project. Accordingly, no loss of availability of minerals of statewide significance or hazards associated with encountering such surface or sub surface deposits of such minerals are anticipated. The effects associated with the loss of availability of a known mineral resource would have no impact under NEPA or CEQA.

Figure 3.9-7 shows the oil and gas fields in the project vicinity. The BNSF alternative crosses several oil fields:

- Fruitvale Oil Field, approximately 1.5 miles to the west of Bakersfield.
- Rosedale Oil Field, approximately 6 miles to the west of Bakersfield.
- Seventh Standard Oil Field between Bakersfield and Shafter.
- Rose Oil Field north of Wasco.

In addition, the Wasco-Shafter Bypass passes through the North Shafter Oil Field. The BNSF Alternative would be elevated over the Fruitvale Oil Field. The alignments would be at-grade through the other oil fields listed above.

Locations of oil wells (both active and abandoned) were plotted from data obtained from the DOGGR database, which was accessed in September 2013. The database contained a total of 61 oil and gas wells within 200 feet of the centerline or within the construction footprints of the following alternatives:

• BNSF (Fresno to Bakersfield)	15 wells
• Wasco-Shafter Bypass	18 wells
• Bakersfield South	14 wells
• Bakersfield Hybrid	14 wells

Of the 61 wells identified in the DOGGR database, 28 are defined as active wells, 8 are new wells, and 25 are plugged. Active wells would need to be capped and abandoned or relocated, potentially to nearby locations using directional drilling techniques, if feasible. Appurtenant facilities such as pipelines would also potentially need to be relocated if they fall within the footprint. Data collected from exploration activities are used to optimize the entrance to the target zone when drilling and developing a well. Therefore, capping an existing well and redrilling into the target zone from a nearby location may not result in the same level of production from the new well. The production rate from a new well cannot be estimated before it is installed. Consequently, it is not certain that a new well will be as productive as the existing well, and it is possible that the replacement well may result in a reduction in the rate of production at the new well. However, production lost during well relocation is expected to be small on a regional basis, due to the small number of affected wells. Wells would be capped, abandoned, or relocated by the well operator with compensation from the Authority. The Authority would compensate well owners for the relocation and drilling of new wells, relocation of ancillary pipelines and underground conveyance, as well as for loss in production in a manner consistent with existing state laws and regulations. The effects associated with the loss of availability of a known petroleum or natural gas resource of regional or statewide value would have negligible intensity under NEPA and the impacts would be less than significant under CEQA. While a small number of individual wells may be affected by the project, the project would not result in damage to the geologic horizons containing the oil or gas, due to the depth of the oil and gas reserves. The project would not result in a loss of access to oil and gas resources.

Unless existing oil and gas wells as well as ancillary and appurtenant facilities necessary to maintain oil field operations are identified and remediated within the project footprint, they could be disrupted and have environmental consequences during construction. Contractors would use safe and explosion-proof equipment during project construction in areas where explosion hazards exist, and would test for gases regularly. Because of this, impacts from construction in areas with subsurface gas or oil would have negligible intensity under NEPA and the impacts would be less than significant under CEQA.

The Fresno to Bakersfield Section of the HST System, including the stations and HMFs, does not cross any areas of known geothermal resources.

Project Impacts

Common Soils-Related Impacts

Similar to the construction period impacts, geologic risks during the project are only different in that the exposure period extends for the life of the project. This longer exposure period increases the potential risks from localized deposits of soft or loose soils, areas with potential for ground settlement, expansive soils with high shrink-swell characteristics and high corrosivity potential, and slope failure. As noted for the construction period considerations, these risks would be managed by conducting investigations and by implementing design methods that conform with construction design standards and building code requirements.

Impact GSS #6 – Effects of Unstable Soils on Operations

The potential for impacts from unstable soils during operations 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 increases. 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.

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.

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 measures that protect the facility from loads associated with unstable soils. With implementation of these design measures, the potential effects from soft or loose soils would have negligible intensity under NEPA, and the impacts would be less than significant under CEQA because loose and unstable soils would be improved or foundations would be designed to avoid impacts to structures from these conditions.

Impact GSS #7 – Effects of Soil Settlement on Operations

Soil settlement could occur during operation of the project due to regional subsidence and on a local scale 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, retained fill, or for track subgrade and ballast materials that are placed to meet track grade requirements. A number of locations along the project footprint would require new earth fills. Some of these areas are potentially underlain by settlement-prone (loose or soft) soils. These specific locations would be identified during preconstruction and construction investigations and engineered solutions would be implemented for site-specific conditions. The potential consequence of excessive settlement represents a high risk to HST travel if unaddressed. However, regional subsidence and localized settlement are typically slow processes that, with periodic maintenance, can be remedied by dressing and or reballasting where required to maintain a safe track profile.

The HST project design incorporates ground improvements and foundations that are resistant to settlement and would meet building code requirements. Additional fill material from other sources would be imported as necessary. Because of this, the potential risk of excessive ground settlement would be minimal and would result in effects with negligible intensity under NEPA and less-than-significant impacts under CEQA.

Impact GSS #8 – Effects of Moderate to High Shrink-Swell Potential on Operations

Soils located in the upper 5 feet of the soil profile along all of the alternatives and at the HMFs generally have moderate-to-high shrink-swell potential (expansive soils). Soils with high shrink-swell potential shrink during dry conditions and expand when soaked. The potential for shrink-swell, if unchecked, represents a risk to the operation of the track system and the track right-of-way for long-term operations. Soils with high shrink-swell potential have been mapped in the vicinity of Hanford, Corcoran, and the southeastern portions of Tulare County. In Kern County, these characteristics have been identified in the southeastern part of Bakersfield.

This type of impact is more critical to locations with at-grade segments than to elevated structures on deep foundations, retained fill, or 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 alignment, leading to differential movement of the track system.

The project design reduces the risk from shrink-swell soils through minimization of moisture content changes, design of surcharge loads to offset swell pressures, or soil improvement, or by removal of the upper 5 feet of soils that exhibit high shrink-swell potential, and replacement of the excavated soils with soils that do not exhibit these characteristics. Implementing one or more of these engineering design measures will reduce risks from shrink-swell soils and result in effects with negligible intensity under NEPA, and less-than-significant impacts under CEQA.

Impact GSS #9 – Effects of Moderately to Highly Corrosive Soils on Operations

Soils along all of the alternatives and at the HMFs generally have moderate to high corrosivity to uncoated steel, as well as concrete in some locations. 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 buried steel or concrete components.

The project design reduces the risk from corrosive soils through soil improvement or by removal of the upper 5 feet of soils that exhibit high-corrosivity characteristics, and by replacement of the excavated soils with soils that do not exhibit these characteristics in areas where there would be buried, uncoated steel. Active and passive corrosion protection systems could also protect embedded and exposed steel structures from corrosion. As necessary, final designs would include epoxy-coated steel or double corrosion-protection ground anchors to avoid long-term corrosion issues.

Standard engineering and design features will be implemented to reduce risks from corrosive soils. This could include importing non-corrosive soils or using coated or corrosion resistant steel or concrete materials. Therefore the project would result in effects with negligible intensity under NEPA, and less-than-significant impacts under CEQA.

Impact GSS #10 – Effects of Slope Failure on Operations

Slopes along some rivers and streams could fail, either from 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. The consequences 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 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. These failures could endanger people and onsite and offsite structures if the HST track were damaged.

The HST project design addresses slope stability by incorporating standard IBC and other engineering standards and criteria. Detailed slope stability evaluations would be conducted and impact avoidance 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, as appropriate, to reduce the potential for future slumps and slope failures. Structural solutions would physically hold cuts in slopes in place with walls or other physical structures, while geotechnical solutions would improve the soils to increase stability or reduce slopes to eliminate slope failure. In the case of elevated structures, the location of the foundation would be sited during final design to avoid the area of slope failure. Because standard engineering and design measures (see Section 3.9.6) would be implemented, effects under NEPA would have negligible intensity, and impacts under CEQA would be less than significant.

Impact GSS #11 – Effects of Seismicity on Operations

Earthquakes could produce hazards to the HST System. These include moderate to high seismic ground motions, e.g., peak ground acceleration, as discussed in Primary Seismic Hazards, and the risks from secondary seismic hazards associated with large seismic-induced ground motions.

Seismic-Induced Ground Shaking

The faults and fault systems that exist to the east, west, and south of the project area are known to produce seismic events capable of causing moderate-intensity ground shaking. The level of ground shaking is estimated to have a peak ground acceleration at the ground surface of 0.24g to 0.41g. The level of ground shaking could vary along the alignments, depending on the amount of ground motion amplification or deamplification within specific soil layers; however, the likely level of seismically induced ground motion is sufficient to cause substantial damage 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, and the retaining walls for retained 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.

A key consideration is the response of the operating HST to a seismic event that shakes the track. Movement of the track bed would be transferred into the train. The train cars, the spring system for the train cars, and the track design would be appropriately configured to resist the resulting inertial response of the train while it is traveling at a high speed. Available information for other HSTs in seismically active areas, such as Japan and Taiwan (see Section 3.11, Safety and Security), suggests that the California HST would be able to satisfy life-safety requirements for the design earthquake.

Definitions

Moments and *shear forces* are engineering terms that refer to forces that develop in structures during seismic loading. During an earthquake, inertial forces often develop above the ground surface, when the mass of the structure accelerates from earthquake shaking. The combination of force and distance above the ground results in a moment above the ground, as would occur for an elevated track supported on a cast-in-drill-hole foundation. Shear develops from the horizontal application of this force to the column. Strict engineering standards must be met so that moments and shear forces are within design values.

The HST design would address seismically induced ground shaking by specifying minimum seismic loading requirements for any elevated structures, and the train's 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 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. In addition, a network of instruments would be installed to provide ground motion data that would be used with the HST instrumentation and controls system to temporarily shut down the HST operations in the event of an earthquake. Appropriate project design features will be implemented that would render seismically induced ground shaking an effect with negligible intensity under NEPA, and a less-than-significant impact under CEQA.

Surface Fault Rupture

The Fresno to Bakersfield Section of the HST (specifically, the BNSF and the Allensworth Bypass alternative alignments) crosses the concealed portion (no surface expression) of Pond Fault approximately 1.2 miles south of the intersection of Pond Road and SR 43. This concealed portion of the fault dates to the Quaternary Period (<2,600,000 years before the present) or older. However, approximately 1.5 miles east of the BNSF Alternative near Pond, California, a trace of the Pond Fault is mapped in the north-south direction. Studies have shown that historical fault movements have occurred on this exposed or mapped portion of the fault; these movements have been periodic or creep-type rather than single abrupt rupture. If damage from fault creep were to occur along these alignments, it would be repaired with routine maintenance, which could include repaving or minor track realignment. Thus, the exposure of people or structures to potential effects from surface fault rupture would have negligible intensity under NEPA, and less than significant impacts under CEQA.

Secondary Seismic Hazards

One of the primary consequences of strong ground shaking could be liquefaction of saturated, loose, cohesionless soils. As noted in Section 3.9.3, Methods for Evaluating Impacts, the soil types in the area and groundwater conditions are generally not conducive to liquefaction because of the coarse soil textures typical of the eastern portion of the San Joaquin Valley, and depth to groundwater. Liquefaction potential can increase in areas where groundwater is less than 50 feet the surface such as near river and stream crossings or in areas where perched shallow groundwater occur. All alternative alignments, including the stations and the alternative HMF sites, would be built on relatively flat terrain; therefore, lateral spreading in response to the liquefaction of subsurface soil caused by gravitational forces is not likely.

Detailed slope-stability evaluations would be conducted, and engineering measures such as ground improvement, use of retaining walls, or regrading of slopes would be implemented, as appropriate, to reduce the potential for seismically induced slope failures; localized instabilities that may occur would be handled as a maintenance issue. These measures would render the risk of liquefaction and seismically induced slope failures an effect with negligible intensity under NEPA, and a less-than-significant impact under CEQA.

The potential dam failures that could result in inundation of the downstream flat-lying areas and potentially affect the alternative alignments are (from north to south) the Redbank Dam, Redbank Detention Dam, Fancher Creek Dam, Pine Flat Dam, Terminus Dam, Success Dam, and Isabella Dam; see Figure 3.9-6 for the locations of these dams. The potential inundation impacts are summarized below:

- Failure of the Redbank, Fancher Creek, and Redbank Detention dams, located approximately 8 miles east of the proposed Fresno Station, would result in floodwaters traveling westerly through Fancher Creek, which meanders to the northwest of Calwa City. Floodwaters would likely inundate portions of the HST alignment from the proposed Fresno Station south to Calwa City.

- Pine Flat Reservoir is located approximately 27 miles to the northeast of the Fresno to Bakersfield Section within the Kings River drainage area. If Pine Flat Dam failed during an earthquake, floodwaters would travel south and southwest through the Kings River drainage area, where they would first intercept the BNSF Alternative about 2.5 miles north of Bowles and then continue to spread to the south to an area east of Hanford, inundating the trackway between Corcoran and Hanford (including the potential Kings/Tulare Regional Station near Hanford).

- Terminus Reservoir (Lake Kaweah) is located approximately 37 miles to the east of the potential Kings/Tulare Regional Station. According to the “Health and Safety Element” of Tulare County (2010b), dam failure at full capacity is considered remote. In the unlikely event of dam failure, floodwaters would be expected to reach portions of Kings County within 12 hours. These waters would cover an approximately 6-mile portion of the HST alignment between Hanford and Corcoran.

- Success Dam is on the Tule River approximately 37 miles east of the BNSF Alternative. According to the Tulare County General Plan, the failure of Success Dam could cause substantial flooding in Tulare County and would likely inundate sections of the BNSF Alternative (Tulare County 2010b). However, the degree of inundation is unknown. The inundation map is currently under revision to show inundation in the case of failure of Success Dam. Success Dam has been operated for a number of years at a lowered pool elevation to reduce the risk of flooding if the dam were to breach. In 2006, regulations were passed that limited long-term water storage in the reservoir to approximately 29,000 acre feet, or about 35% of capacity (U.S. Bureau of Reclamation 2009). Studies have been conducted for a dam remediation program to reduce the risk of dam failure and the USACE recently determined that the safety concerns were not as severe as once thought. After several years that saw the peak storage held below 40,000 acre feet, in 2012 the USACE allowed 65,000 acre feet to be stored (Porterville Recorder 2012).

- Isabella Dam is located approximately 37 miles to the northeast of Bakersfield. The 2008 USACE flood maps for Lake Isabella Dam show that an approximately 15-mile section of the BNSF Alternative could be inundated by as much as 20 feet of water. It would take an estimated 6 to 8 hours for escaped water to reach a flooding depth of 1 foot at the proposed Bakersfield Station (Kern County Planning Department 2007b). Thus, in the unlikely event that Lake Isabella Dam did fail, this should allow ample time to evacuate HST facilities and tracks. Also, a portion of this section of the BNSF Alternative is elevated near the station. It should be noted that Lake Isabella Dam is being operated (at the time this document was being prepared) at a lowered pool elevation (no more than 66% of its capacity) to reduce the risk of flooding if the dam were to breach. Studies are under way on a dam remediation program to reduce the risk of dam failure. Therefore, the risk of impacts on the proposed HST would ultimately be improved and presumably eliminated.

A seismically induced dam failure on one or more of the dams would be an unlikely event because the seismic event would need to be large enough to cause catastrophic damage to the dam structure. For the Fresno to Bakersfield Section, including the station alternatives and the alternative HMF sites, the impacts associated with exposing people or structures to inundation hazards resulting from seismically induced dam failure are anticipated to result in effects with negligible intensity under NEPA and less-than-significant impacts under CEQA. This is because dam failure is a very unlikely event and the amount of time before inundation of the portions of the HST System (on the order of several hours) would allow for evacuation of people from the system.

3.9.6 Project Design Features

Project design will incorporate engineering measures and BMPs based upon federal and state regulations and on the Statewide Program EIR/EIS (Authority and FRA 2005) to avoid, minimize, or reduce potential adverse impacts. Site-specific geotechnical investigations will be carried out as design work progresses so that the project can incorporate site-specific engineering solutions that adhere to regional and national technical standards and codes into the design to reduce risks associated with the geology, soils, and seismicity. Applicable design standards for Geology, Soils, and Seismicity that would be used for the project are provided in Appendix 2-D. The technical standards and codes include the following:

- **2010 AASHTO Load Resistance Factor Designs (LRFD) Bridge Design Specifications 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, retaining walls, and buried structures. These design specifications will provide minimum specifications for evaluating the seismic response of the soil and structures.

- **Federal Highway Administration (FHWA) 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:** These guidelines deal with rail systems. Although they cover many of the same general topics as 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 the 2009 IBC. This code contains general building design and construction requirements relating to fire and life safety, structural safety, and access compliance.

- **IBC and ASCE 7:** These codes and standards provide minimum design loads for buildings and other structures. They will be used for the design of the maintenance facilities and stations. Sections in 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. These amendments provide specific guidance for the design of deep foundations that are 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.

- **Caltrans Construction Manuals:** Caltrans has a number of manuals including Field Guide to Construction Dewatering, Caltrans Construction Site Best Management Practices (BMPs) Manual and Construction Site Best Management Practice (BMP) Field Manual and Troubleshooting Guide that provide guidance and Best Management Practices for dewatering options and management, erosion control and soil stabilization, non-storm water management, and waste management at construction sites.

- **American Society for Testing and Materials (ASTM):** ASTM has developed standards and guidelines for all types of material testing—from soil compaction testing 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 ensure that quality is achieved in the constructed project.

To manage geologic, soils, and seismic hazards, site-specific geotechnical investigations will be conducted and, based on that information, the project will implement the following specific measures to reduce and avoid impacts during construction and operation. These practices include the following:

- **Limit Groundwater Withdrawal:** Control the amount of groundwater withdrawal from the project, re-inject groundwater at specific locations if necessary, or use alternate foundation designs to offset the potential for settlement. This control is important for locations with retained cuts in areas where high groundwater exists, 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.

- **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:** Employ various methods to mitigate for the risk of ground failure from unstable soils. If the soft or loose soils are shallow, they can be excavated and replaced with competent soils. To limit the excavation depth, replacement materials can also be strengthened using geosynthetics. Where unsuitable soils are deeper, ground improvement methods, such as stone columns, cement deep-soil-mixing (CDSM), or jet-grouting, can be used. Alternatively, 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. Lime treatment of heavy rail subgrades over soft soils has also been used successfully in the San Joaquin Valley. 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. Alternatively, at these locations, earth fills might be replaced by lightweight fill, such as lightweight concrete, extruded polystyrene (geofoam), or short columns, and cast-in-drilled 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 in areas that are predicted to undergo excessive settlement. By using the preload and surcharge with wick drains, settlement would be forced to occur. 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 use well points in combination with sheet pile walls to limit the amount of settlement of adjacent properties from temporary water drawdown. Alternately, water can be re-injected to make up for localized water withdrawal.

- **Prevent Water and Wind Erosion:** Many mitigation methods exist for controlling water and wind erosion of soils. These include the use of straw bales and mulches, revegetation, and covering areas with geotextiles. Where the rate of water runoff could be high, riprap and riprap check dams could be used to slow the rate of water runoffs. Other BMPs for water are discussed in Section 3.8, Hydrology and Water Resources. Implementation of these methods is important where large sections of earth are exposed during construction, such as for retained-cut design segments.

- **Modify or Remove and Replace Soils with Shrink-Swell Potential and Corrosion Characteristics:** One option is to excavate and replace soils that represent the highest risk. In locations where shrink-swell potential is marginally unacceptable, soil additives will 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.

- **Evaluate and Design for Large Seismic Ground Shaking:** Prior to final design, additional seismic studies will be conducted to establish the most up-to-date estimation of levels of ground motion. Updated Caltrans seismic design criteria will be used 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 will 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 mitigate 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, stone columns, EQ drains or jet-grouting develop resistance to lateral flow or spreading of liquefied soils.

- **Suspend Operations During or After an Earthquake:** Install motion-sensing instruments to provide ground-motion data; install a control system to shut down HST operations temporarily during or after a potentially damaging earthquake to reduce risks. Monitors will be installed at select locations where high ground motions could damage the HST track system. Candidate locations would include, but are not limited to, elevated guideways and retained-earth, retained-cut, and at-grade segments.

3.9.7 NEPA Impact Summary

This section identifies effects for both the No Project Alternative and the HST project alternatives. Under the No Project Alternative, the California HST System would not be built and the effects associated with geology, soils, and seismicity under current conditions would continue, including effects from continued operation of existing highways, airports, and railways. Other projects planned for construction, including transportation improvement projects, would be required to comply with federal and state regulatory requirements and to implement design requirements during construction and operation to minimize effects associated with geology, soils, and seismicity. Potential effects associated with the No Project Alternative are considered to be of negligible intensity in the localized context of unstable or corrosive soils, as well as in the regional context of the geologic and seismic conditions of the San Joaquin Valley.

Effects for the project alternatives associated with geology, soils, and seismicity would be of negligible intensity in the regional geological and seismic context of the San Joaquin Valley, are not significant under NEPA, and are summarized as follows:

- Construction and long-term operation of the project alternatives, stations, and HMF on localized soft or loose soils could result in onsite or offsite slumps and small slope failures at stream crossings, in the instability of cut-and-fill slopes required for the track, or in the collapse of retaining structures associated with retained cuts or retained fills; effects would be of negligible intensity with the implementation of standard engineering design measures.

- Differential settlement of soft or loose soil that supports structures and the 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 stations and HMFs, would be negligible with the incorporation of such design measures as excavating underlying settlement-prone (loose or soft) soils, and augmenting them with new earth.

- Wind or water erosion of soil during both construction and operation are considered impacts of negligible intensity with the implementation of standard design measures and BMPs.

- The potential for shrink-swell represents a risk of negligible intensity to the operation of the track system and the track right-of-way for long-term operations with the implementation of standard design measures, such as excavating underlying expansive soils and augmenting them with an imported soil base.

- The potential for corrosion of uncoated steel and concrete represents a risk of negligible intensity to the operation of the track system and the track right-of-way for long-term operations with the implementation of standard design measures, such as excavating underlying corrosive soils and augmenting them with an imported soil base or using treated materials to reduce the effects of corrosive soils.

- The intensity of the risk to the project from slope failure at stream crossings due to unstable soils is considered to be negligible with implementation of standard structural engineering design measures.
- Effects on oil and gas production would be of negligible intensity under NEPA.
- Effects from seismically induced ground motion are expected to be of negligible intensity with implementation of standard design measures.

3.9.8 CEQA Significance Conclusions

Because standard engineering design measures and BMPs are incorporated into the project, the potential impacts discussed above related to geology, soils, and seismicity 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.