3.9 Geology, Soils, Seismicity, and Paleontological Resources

3.9.1 Introduction

This section describes geology, soils, seismicity, and paleontological resources in the San Francisco to San Jose Project Section (Project Section, or project) resource study area (RSA) where geology, soils, seismicity, and paleontological resources are most susceptible to change as a result of construction and operations of the project. Geology, soils, and seismicity include the Earth's physical structure, materials, history, and processes. Paleontological resources (fossils) are the preserved remains or traces of animals, plants, protozoans, fungi, and bacteria that can provide important information about the evolution of life on Earth over the past 3 billion years or more.

Geology, Soils, and Seismicity—Key Issues

- Geologic hazards resulting in damage to structures or loss of life
- Exposure of people or structures to loss of life, injuries, or destruction due to primary and secondary seismic activity

Paleontology—Key Issue

- Ground disturbance resulting in damage or loss of paleontological resources (fossils) contained within substrate materials

The *San Francisco to San Jose Project Section Geology, Soils, and Seismicity Technical Report* (San Francisco to San Jose Geology, Soils, and Seismicity Technical Report) (California High-Speed Rail Authority [Authority] 2019a) and the *San Jose to Merced Project Section Geology, Soils, and Seismicity Technical Report* (San Jose to Merced Geology, Soils, and Seismicity Technical Report) (Authority 2019b) provide additional technical details on geologic resources and geologic hazards. The *San Francisco to San Jose Project Section Paleontological Resources Technical Report* (San Francisco to San Jose Paleontological Resources Technical Report) (Authority 2019c) and the *San Jose to Merced Project Section Paleontological Resources Technical Report* (San Jose to Merced Paleontological Resources Technical Report) (Authority 2019d) provide additional technical details on paleontological resources.[1]

The following appendices in Volume 2, Technical Appendices, of this Draft Environmental Impact Report (EIR)/Environmental Impact Statement (EIS) provide additional details on project features related to geology, soils, seismicity, and paleontological resources:

- Appendix 2-D, Applicable Design Standards, describes the relevant design standards for the project.
- Appendix 2-E, Project Impact Avoidance and Minimization Features, provides the list of all impact avoidance and minimization features (IAMF) incorporated into this project.
- Appendix 2-I, Regional and Local Plans and Policies, provides a list by resource of all applicable regional and local plans and policies.

Geology, soils, and seismicity are important factors for designing and building a safe, cost-effective, and environmentally sound project. The geologic setting is also an important area for paleontological resources. The following three Draft EIR/EIS resource sections provide additional information related to geologic and paleontological resources:

- Section 3.8, Hydrology and Water Resources, evaluates impacts of the project alternatives on surface water hydrology, water quality, groundwater, floodplains, and soil erosion.
- Section 3.10, Hazardous Materials and Wastes, evaluates impacts of the project alternatives on hazardous materials and waste sites.

[1] Technical reports for the San Francisco to San Jose Project Section evaluate the portions of the HSR alignment between 4th and King Street Station in San Francisco and Scott Boulevard in Santa Clara, while technical reports for the adjacent San Jose to Merced Project Section evaluate the portions of the HSR alignment south of Scott Boulevard to the Project Section terminus at West Alma Avenue south of the San Jose Diridon Station.

- Section 3.11, Safety and Security, evaluates impacts of the project alternatives on the earthquake safety of the high-speed rail (HSR) system.

3.9.2 Laws, Regulations, and Orders

This section presents federal, state, and local laws, regulations, orders, and plans applicable to geology, soils, seismicity, and paleontology. The Authority would implement the HSR system, including this project, in compliance with all federal and state regulations. Regional and local plans and policies relevant to geology, soils, seismicity, and paleontological resources considered in the preparation of this analysis are provided in Volume 2, Appendix 2-I.

3.9.2.1 Geology, Soils, and Seismicity

Federal

Procedures for Considering Environmental Impacts (64 Fed. Reg. 28545)

These Federal Railroad Administration (FRA) procedures state that an EIS should consider possible impacts on energy and mineral resources.

State

Alquist-Priolo Earthquake Fault Zoning Act (Cal. Public Res. Code § 2621 et seq.)

The Alquist-Priolo Earthquake Fault Zoning Act was signed into law December 22, 1972, and went into effect March 7, 1973. The purpose of the act was to regulate development near active faults in order to mitigate the hazard of surface fault rupture. In general, the act has two requirements: prohibiting the location of “developments and structures for human occupancy” across the trace of active faults, and establishing Earthquake Fault Zones as defined by the State Geologist, within which affected cities and counties must establish special procedures for reviewing and approving applications for new building permits.

Seismic Hazards Mapping Act (Cal. Public Res. Code §§ 2690–2699.6)

The State Legislature passed the Seismic Hazards Mapping Act in 1990, which was codified in the California Public Resources Code (Cal. Public Res. Code) as Division 2, Chapter 7.8, which became operative on April 1, 1991. The purpose of the act is to identify areas where earthquakes are likely to cause shaking, liquefaction, landslides, or other ground failure, and to regulate development to reduce future earthquake losses. The California Geological Survey (CGS) has responsibility for developing the hazard maps and has incrementally focused their efforts on the highest risk areas and areas undergoing significant development. This act requires that site-specific hazards investigations be conducted by licensed professionals 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.

Geologic Hazard Abatement Districts (Cal. Public Res. Code, Division 17, §§ 26500–26654)

The Beverly Act of 1979 (Senate Bill 1195) established geologic hazard abatement districts (GHAD) and allowed local residents to collectively mitigate geological hazards that pose a threat to their properties. GHADs may be formed for the following purposes: prevention, mitigation, abatement, or control of a geologic hazard; and mitigation or abatement of structural hazards that are partly or wholly caused by geologic hazards. Cal. Public Res. Code defines a geologic hazard as “an actual or threatened landslide, land subsidence, soil erosion, earthquake, fault movement, or any other natural or unnatural movement of land or earth.”

Surface Mining and Reclamation Act (Cal. Public Res. Code § 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. The act also assigns specific responsibilities to local jurisdictions in permitting and oversight of mineral resources extraction activities.

Sustainable Groundwater Management Act (Cal. Water Code § 10720)

The Sustainable Groundwater Management Act was signed into California law in 2014 and requires California governments and water agencies of high- and medium-priority groundwater basins to halt aquifer overdraft by balancing pumping and recharge levels.

California Building Standards Code (Cal. Public Res. Code tit. 24)

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

Oil and Gas Conservation (Cal. Public Res. Code §§ 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 and public safety, and prevent pollution.

California Administrative Code (Cal. Code Regs., tit. 14, §§ 4307–4309)

The sections of the California Administrative Code relating to the State Division of Beaches and Parks afford protection to geologic features and "paleontological materials" but also assign the director of the state park system the authority to issue permits for activities that may result in damage to such resources, if the activities are for state park purposes and are in the interest of the state park system.

Construction General Permit (California State Water Resources Control Board Order No. 2009-0009-DWQ NPDES No. CAS000002)

Construction projects that disturb 1 or more acres of soil or that disturb less than 1 acre but are part of a larger common plan of development are required to obtain stormwater coverage under the statewide General Permit for Discharges of Storm Water Associated with Construction Activity (also referred to as the Construction General Permit). The permit requires temporary and post-construction best management practices (BMP) and measures to prevent erosion and reduce sediment and pollutants in discharges from construction sites.

Regional and Local

Volume 2, Appendix 2-I, lists all regional and local policies that are applicable to the project. The geology, soils, and seismicity standards included in regional and local policies restate, or incorporate by reference, geologic and seismic hazards guidelines set forth in federal and state regulations and industry standards.

3.9.2.2 *Paleontological Resources*

Federal

American Antiquities Act of 1906 (16 U.S.C. §§ 431–433)

The American Antiquities Act was enacted with the primary goal of protecting cultural resources in the United States. Accordingly, it prohibits appropriation, excavation, injury, or destruction of "any historic or prehistoric ruin or monument, or any object of antiquity" located on lands owned or controlled by the federal government. The act also establishes penalties for such actions and sets forth a permit requirement for collection of antiquities on federally owned lands.

Neither the American Antiquities Act itself nor its implementing regulations (43 Code of Federal Regulations [C.F.R.] Part 3) specifically mentions paleontological resources. However, many federal agencies have interpreted objects of antiquity as including fossils. Consequently, the act represents an early cornerstone of efforts to protect the nation's paleontological resources.

Paleontological Resources Preservation Act (16 U.S.C. § 470aaa)

Enacted as part of the Omnibus Public Land Management Act (2009), the Paleontological Resources Preservation Act requires the Secretaries of the Interior and Agriculture to manage and protect paleontological resources on federal land using scientific principles and expertise. The act includes specific provisions addressing management of these resources by the Bureau of Land Management, National Park Service, Bureau of Reclamation, U.S. Fish and Wildlife Service, and U.S. Forest Service of the Department of Agriculture. The act affirms the authority for many of the policies the federal land managing agencies already have in place for the management of paleontological resources, such as issuing permits for collecting paleontological resources, curation of paleontological resources, and confidentiality of locality data.

State

California Environmental Quality Act (Cal. Public Res. Code § 21000 et seq.) and CEQA Guidelines for Protection of Paleontological Resources

The California Environmental Quality Act (CEQA) statute includes "objects of historic … significance" in its definition of the environment (Cal. Public Res. Code § 21060.5), and Section 15064.5 of the CEQA Guidelines further defines historical resources as including "any object…site, area, [or] place… that has yielded, or may be likely to yield, information important in prehistory." This has been widely interpreted as extending CEQA consideration to paleontological resources. The cultural resources section of the CEQA Guidelines Appendix G sample environmental checklist reflects this perspective, and includes a question asking whether the proposed project would "directly or indirectly destroy a unique paleontological resource or site." However, neither the CEQA statute nor the CEQA Guidelines defines what constitutes a "unique paleontological resource" or a "unique paleontological site" and thus merits consideration per this checklist item. Neither the CEQA statute nor the CEQA Guidelines gives direction regarding the treatment of paleontological resources in general (unique and nonunique) under CEQA. Because of the breadth of the CEQA definition of "historical resources," the general guidance regarding significance determinations in Section 15064.5(b) of the CEQA Guidelines may be interpreted as applying to impacts on paleontological resources, but this chapter focuses for the most part on factors specifically related to eligibility for state and local register listing; it does not address the essence of "[yielding] information important in prehistory" from a paleontological perspective. The most relevant guidance appears in CEQA Guidelines Section 15064.5(b)(1), which defines a "[s]ubstantial adverse change in the significance of an historical resource"—and by extension, a significant impact on such resources, including paleontological resources—as the "physical demolition, destruction, relocation, or alteration of the resource or its immediate surroundings such that … [its] significance … would be materially impaired."

California Public Resources Code

The Cal. Public Res. Code protects paleontological resources in specific contexts. In particular, Cal. Public Res. Code Section 5097.5 prohibits "knowing and willful" excavation, removal, destruction, injury, and defacement of any paleontological feature on public lands without express authorization from the agency with jurisdiction. Violation of this prohibition is a misdemeanor and is subject to a fine and/or imprisonment (Cal. Public Res. Code § 5097.5(c)), and persons convicted of such a violation may also be required to provide restitution (Cal. Public Res. Code § 5097.5(d)(1)). Additionally, Cal. Public Res. Code Section 30244 requires "reasonable mitigation measures" to address impacts on paleontological resources identified by the State Historic Preservation Officer.

Regional and Local

Volume 2, Appendix 2-I lists all regional and local policies that are applicable to the project. The paleontological resource standards included in regional and local policies restate, or incorporate by reference, guidelines for paleontological resources set forth in federal and state regulations and industry standards.

3.9.3 Consistency with Plans and Laws

As indicated in Section 3.1.5.3, Consistency with Plans and Laws, CEQA and National Environmental Policy Act (NEPA) regulations[2] require a discussion of inconsistencies or conflicts between a proposed undertaking and federal, state, regional, or local plans and laws. As such, this Draft EIR/EIS describes the inconsistency of the project alternatives with federal, state, regional, and local plans and laws to provide planning context.

3.9.3.1 Geology, Soils, and Seismicity

There are a number of federal and state laws and implementing regulations, listed in Section 3.9.2.1, Geology, Soils, and Seismicity, under subsections Federal and State, that govern compliance with construction and operations standards relating to geology, soils, and seismicity for construction projects and transportation facilities. A summary of the federal and state requirements considered in this analysis follows:

- FRA guidelines for consideration of possible effects on energy and mineral resources
- State laws that govern construction in areas of known seismic activity
- State laws that address construction in or near areas of energy and mineral extraction activity
- State guidelines governing construction with respect to geologic and soils hazards

The Authority, as the lead agency proposing to build and operate the HSR system, must comply with all federal and state laws and regulations and secure all applicable federal and state permits prior to initiating construction of the selected alternative. Therefore, there would be no inconsistencies between the project alternatives and these federal and state laws and regulations.

The Authority is a state agency and therefore is not required to comply with local land use and zoning regulations; however, it has endeavored to design and construct the project to be consistent with land use and zoning regulations. For example, the project alternatives would incorporate an IAMF that requires the contractor to evaluate and take into account soil vulnerabilities, as local ordinances also require. The Authority would also adopt a monitoring program to track any subsidence during operations. The Authority reviewed a total of 29 plans and 126 policies, goals, objectives, implementation actions, implementation programs, and implementation measures related to geology, soils, and seismicity. The project alternatives are consistent with all plans, codes, policies, and goals for geology, soils, and seismicity because construction practices, infrastructure design, and operations would be consistent with established building standards relevant to geotechnical issues.

3.9.3.2 Paleontological Resources

Section 3.9.2.2, Paleontological Resources, lists a number of federal and state laws and implementing regulations that protect paleontological resources. These federal and state requirements include:

- Federal regulations that address paleontological resources on federally owned or controlled lands
- State regulations that address paleontological resources on state and public (state, county, city, special district, public authority, and public corporation) lands

The Authority, as the lead agency proposing to build and operate the HSR system, must comply with all federal and state laws and regulations and secure all applicable federal and state permits prior to initiating construction on the selected alternative. Therefore, there would be no inconsistencies between the project alternatives and these federal and state laws and regulations.

The IAMFs for paleontological resources incorporate specific actions to protect scientifically important paleontological resources and avoid the loss of scientific information, consistent with prevailing Society of Vertebrate Paleontology (SVP) guidance (the SVP Standard Guidelines,

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[2] NEPA regulations refer to the regulations issued by the Council for Environmental Quality located at 40 C.F.R. Parts 1500–1508.

Conditions of Receivership, and Standard Procedures) and the overall objectives of federal laws protecting paleontological resources. Moreover, with the IAMFs in place, any collection of paleontological resources during construction of the selected alternative would occur with the authorization and oversight of the Authority and would be conducted by qualified paleontological staff in a manner consistent with the prevailing discipline standard for paleontological resources recovery and curation. Consequently, the project alternatives are considered consistent with the objectives of federal and state regulations that require science-based management of paleontological resources and prohibit unauthorized disturbance, destruction, and removal of such resources.

The Authority is a state agency and therefore is not required to comply with local land use and zoning regulations; however, it has endeavored to design and construct the HSR system so that it is consistent with land use and zoning regulations, including goals and policies protecting paleontological resources. The Authority reviewed a total of 15 plans and 74 policies, goals, objectives, implementation actions, implementation programs, and implementation measures. The Authority's standard paleontological resources methodology guidelines (Authority and FRA 2017a) guided the development and content of the paleontological resources IAMFs incorporated into the project alternatives. As the project requires review of 90 percent design and development of specific language detailing paleontological monitoring and other requirements to protect paleontological resources (GEO-IAMF#11: Engage a Qualified Paleontological Resource Specialist), the project alternatives are consistent with all plans, codes, policies, and goals for paleontological resources because the design is consistent with standards of professional practice.

3.9.4 Methods for Evaluating Impacts

3.9.4.1 Impact Avoidance and Minimization Features

IAMFs are project features that are considered to be part of the project and are included as applicable in each of the alternatives for purposes of the environmental impact analysis. The full text of the IAMFs that are applicable to the project is provided in Volume 2, Appendix 2-E. The following IAMFs are applicable to the geology, soils, seismicity, and paleontological resources analysis:

- GEO-IAMF#1: Geologic Hazards
- GEO-IAMF#2: Slope Monitoring
- GEO-IAMF#3: Gas Monitoring
- GEO-IAMF#6: Ground Rupture Early Warning Systems
- GEO-IAMF#7: Evaluate and Design for Large Seismic Ground Shaking
- GEO-IAMF#8: Suspension of Operations During an Earthquake
- GEO-IAMF#9: Subsidence Monitoring
- GEO-IAMF#10: Geology and Soils
- GEO-IAMF#11: Engage a Qualified Paleontological Resources Specialist
- GEO-IAMF#12: Perform Final Design Review and Triggers Evaluation
- GEO-IAMF#13: Prepare and Implement Paleontological Resources Monitoring and Mitigation Plan (PRMMP)
- GEO-IAMF#14: Provide WEAP Training for Paleontological Resources
- GEO-IAMF#15: Halt Construction, Evaluate, and Treat if Paleontological Resources Are Found
- HYD-IAMF#3: Prepare and Implement a Construction Stormwater Pollution Prevention Plan

This environmental impact analysis considers these IAMFs as part of the project design. In Section 3.9.6, Environmental Consequences, each impact narrative describes how these project features are applicable and, where appropriate, effective at avoiding or minimizing potential impacts to less than significant under CEQA.

3.9.4.2 Geology, Soils, and Seismicity

The following discussion describes the methods used to establish the geological setting in the RSA, and to determine the impacts of construction and operations on geology, soils, and seismicity. The methods involved review and assessment of publicly available data when establishing potential impacts. The RSA was developed to represent the localized (within project footprint) and regional areas of impact.

Definition of Resource Study Area

Table 3.9-1 describes the RSAs for geology, soils, and seismicity. The RSAs extend beyond the project footprint and into the subsurface beneath the project, such that the RSAs are three-dimensional.

Table 3.9-1 Definition of Geology, Soils, and Seismicity Resource Study Areas

Type	General Definition
Geology, Soils, and Seismicity RSA	
Construction and operations	150 feet on either side of the project footprint for geologic conditions and soils
Geologic Hazards RSA	
Construction and operations	0.5 mile on either side of the project footprint; the buffer is increased to 2 miles around maintenance sites and stations
Seismicity, Faulting, and Dam Failure Inundation RSA	
Construction and operations	50-mile radius on either side of the project footprint

RSA = resource study area

Methods for Impact Analysis

The methods used for performing impact analysis included review of information from published maps, professional publications, and reports pertaining to the geology, soils, and seismicity in the vicinity of the project. The Authority studied the relevant information and assessed the effects of the project related to geology, soils, and seismicity. Chapter 4, Methods for Evaluating Effects, of the Geology, Soils, and Seismicity Technical Reports (Authority 2019a, 2019b), describes the information used for the analysis.

Primary Data Sources for Impact Analysis

- Geologic maps
- Geohazard maps (e.g., landslides and liquefaction)
- Soil maps
- Topographic maps
- Aerial photographs
- Reports by the Authority and others

The impacts analysis evaluates the potential of the project to directly or indirectly cause potential substantial adverse effects, including the risk of loss of life, injury or death and damage to property as a result of geologic hazards, primary seismic hazards, and secondary seismic hazards. The analysis also evaluates the potential for the project to cause soil erosion or reduce the availability of mineral, fossil fuel, and geothermal resources.

Method for Evaluating Impacts under NEPA

Council on Environmental Quality (CEQ) NEPA regulations (40 C.F.R. Parts 1500–1508) provide the basis for evaluating project effects (as described in Section 3.1.5.4, Methods for Evaluating Impacts). As described in Section 1508.27 of these regulations, the criteria of context and intensity are considered together when determining whether a project action would affect a resource.

- **Context**—For this analysis, the *context* would include the type, quality, and sensitivity of the resource involved; the location; or the geographical extent of the effect (national, regional, or local). For the analysis of geology, soils, and seismicity, the context would include the proximity to geologic and seismic hazards of concern, such as active faults and mapped landslide areas; the relative risk levels (i.e., low, moderate, high) of these hazards in proximity to the project; and the potential for occurrence of energy and mineral resources.
- **Intensity**—For this analysis, *intensity* is determined by the potential duration of exposure to geologic and seismic hazards (e.g., during excavation activity, duration of project operations), the potential for geologic and seismic hazards to occur during construction and operations (e.g., frequency of large earthquakes), the degree or severity to which the project could affect public safety and property associated with geologic and seismic hazards, and the volume of mineral or energy resources that would be unavailable for extraction or number and size of mineral operations that would have restricted access. To inform the severity of impact, the analysis compares the impacts of the project alternatives to those associated with the No Project Alternative.

Method for Determining Significance under CEQA

The analysis of risks to the project from existing geological conditions is for information purposes only, and no CEQA significance finding is required. However, for this analysis the project would result in a significant impact related to geology, soils, or seismicity if it would:

- Directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury or death, beyond what people are exposed to currently in the area's environment due to: seismic activity or its related hazards; fault rupture;[3] strong seismic ground shaking; ground failure including liquefaction; dam failure, seiche, or tsunami; or landslides
- Result in substantial soil erosion or the loss to topsoil in a large area that adversely affects the viability of the ecosystem or productivity of farming present in the area
- Be located on a geologic unit or soil that is unstable or that renders a currently stable geologic unit or soil unstable to a degree that it would result in increased exposure of people to loss of life or structures to destruction due to geologic hazards, such as primary and secondary seismic hazards
- Be constructed on expansive soil or corrosive soils as defined in Table 18-1-B of the Uniform Building Code (1994, or most recent applicable Uniform Building Code, International Building Code, or California Building Code) creating substantial direct or indirect risks to life or property as a result of the soils' nature; for instance, causing the collapse of the structure
- Make a known petroleum or natural gas resource of regional or statewide value unavailable to extraction through the physical presence of the project either at the ground surface or subsurface
- Result in the loss of availability of a locally important mineral resource recovery site
- Be located in an area of subsurface gas hazard, including landfill gas, and provide a route of exposure to that hazard that results in a substantial risk of loss of life or destruction of property

[3] Refer to the most recent Alquist-Priolo Earthquake Fault Zoning map issued by the State Geologist for the area or other substantial known evidence of known faults to identify known faults in the project area: Special Publication No. 42 (CGS 2018a).

3.9.4.3 Paleontological Resources

Professional Standards and Authority's Environmental Methodology Guidelines

Although federal and state regulations establish protection for paleontological resources, the legal framework is nonspecific regarding some critical details:

- What resources merit protection?
- What constitutes a significant adverse effect on those resources?
- What level of protection is adequate?

This gap has been filled in two ways: through processes and protocols developed by individual practitioners and professional societies and through guidelines developed by federal, state, and local lead agencies under NEPA and CEQA, respectively.

To comply with applicable laws, the SVP, a scientific organization of professional vertebrate paleontologists, has established standard guidelines (SVP 1996, 2010) that outline acceptable professional practices in the conduct of paleontological resource assessments and surveys; monitoring and mitigation; data and fossil recovery; sampling procedures; museum curation; and specimen preparation, identification, and analysis. A consensus of professional paleontologists approved the SVP's standard guidelines, and they are the standard against which many paleontological monitoring and mitigation programs are judged. Most professional paleontologists in California adhere closely to the SVP's assessment, mitigation, and monitoring requirements as spelled out in these standard guidelines. Many regulatory agencies as well as many county and city agencies have either formally or informally adopted the SVP's standard guidelines for the mitigation of construction-related impacts on paleontological resources. In addition, the SVP (2010) standard guidelines are in accordance with the specific reporting and monitoring requirements set forth in the California Department of Transportation (Caltrans) *Standard Environmental Reference* (Caltrans 2017). Briefly, SVP guidelines require literature and museum archival reviews for each project, as well as a field survey, and, if there is a high potential for disturbing significant fossils during project construction, a mitigation plan that includes monitoring by a qualified paleontologist to salvage fossils encountered, identify salvaged fossils and determine their significance, and place curated fossil specimens into a permanent paleontological repository (e.g., public museum or other institution with a permanent curator on staff).

The portion of the *California High Speed Rail Project EIR/EIS Environmental Methodology Guidelines Version 5.09* (Version 5 Environmental Methods) (Authority and FRA 2017a) that addresses paleontological resources was based largely on the methodology laid out in Chapter 8, Paleontology, of the Caltrans *Standard Environmental Reference* (Caltrans 2017). The Caltrans methodology is a good model for Authority needs because it is not only consistent with the discipline-standard SVP Standard Guidelines/Standard Procedures but was also developed to meet Caltrans' responsibilities under both NEPA and CEQA. The key difference between the Caltrans approach and the Authority's Version 5 Environmental Methods is that the latter replaced Caltrans' multiple sequential technical reports with a single project-specific technical report that meets the requirements of both the Caltrans Paleontological Identification Report and Paleontological Evaluation Report. This approach streamlines the technical report preparation process without loss of scientific substance.

NEPA and CEQA require the evaluation of impacts on paleontological resources. The following sections describe the RSA and the methods used to analyze paleontological resources.

Definition of Resource Study Area

Table 3.9-2 describes the RSA for paleontological resources, which encompasses the areas directly or indirectly affected by construction and operations. The RSAs for direct and indirect impacts are identical. The maximum subsurface depth of the RSA for the proposed station upgrades, elevated areas, tunneling, and at-grade areas is yet to be determined.

Table 3.9-2 Definition of Paleontological Resource Study Area

Type	General Definition
Construction and operations	Affected geologic units throughout their geographic extent; includes units exposed at the surface within the project footprint and a surrounding 150-foot-wide buffer, as well as those present in the subsurface below this area, to the depth potentially encountered by construction or operations.

RSA = resource study area

Methods for Impact Analysis

Primary Data Sources for Paleontological Impact Analysis

- Geologic maps
- Geologic cross sections
- Paleontological record searches
- Scientific literature
- Reports by the Authority and others
- Criteria outlined in the SVP standard guidelines

The methods used for performing the paleontological impact analysis included a resource inventory consisting of review of information from published geologic maps, cross sections, record searches of pertinent local and regional museum repositories, scientific literature, and reports pertaining to the geology and paleontology near the project alignment. Using baseline information gathered during the paleontological resource inventory, the Authority determined the paleontological resource potential ranking of each geologic unit within the RSA using the criteria outlined in the SVP standard guidelines (SVP 2010). Because the Version 5 Environmental Methods adopted by the Authority for the HSR project are based on a combination of SVP and Caltrans guidelines, Table 3.9-3 describes the SVP (2010) rankings and compares it to the Caltrans tripartite scale.

The HSR program defines significant fossils as those that provide taxonomic, taphonomic, phylogenetic, stratigraphic, ecologic, or climatic information. Significant fossils may include body fossils, traces, tracks, and trackways. This usage is consistent with both the Caltrans and SVP approaches (Caltrans 2017; SVP 2010). The Authority evaluated the risk to paleontological resources based on the anticipated three-dimensional extent of ground disturbance and the paleontological potential (potential to contain significant fossils) of the geologic units involved. This analysis was qualitative, yet considered the proportion of disturbance extent (based on the project description and the proposed earthwork volumes for each project alternative), and the extent of potential damage or loss of information. The *San Francisco to San Jose Project Section Paleontological Resources Technical Report* (Authority 2019c) and the *San Jose to Merced Project Section Paleontological Resources Technical Report* (Authority 2019d) describe the information used for the analysis in detail.

Table 3.9-3 Evaluation of Paleontological Sensitivity/Paleontological Potential

SVP Resource Potential	Caltrans Tripartite Scale	Sensitivity Criteria
No potential	No potential	Geologic units of intrusive igneous origin, most extrusive igneous rocks, and medium- to high-grade metamorphic rocks are classified as having no potential for containing significant paleontological resources.
Low potential	Low potential	This category includes geologic units that are potentially fossiliferous, based upon review of available literature and museum collections records, but have yielded few, if any, significant fossils in the past; or, have not yielded fossils, but possess a potential for containing fossil remains; or contain common and/or widespread invertebrate fossils (if the taxonomy, phylogeny, and ecology of the species are well understood). Geologic units of low potential also include those that yield fossils only on rare occasion or under unusual circumstances, eolian deposits, geologic units younger than 10,000 years; and deposits that exhibit a high degree of diagenetic alteration.
Undetermined potential	N/A	In some cases, available literature on a particular geologic unit is scarce and a determination of whether it is fossiliferous or potentially fossiliferous is difficult to make. Under these circumstances, the sensitivity is unknown and further study is needed to determine the unit's paleontological resource potential.
High potential	High potential	Geologic units with high potential for paleontological resources are those that, based on previous studies, have proven to yield vertebrate or significant invertebrate, plant, or trace fossils in the past or are likely to contain new vertebrate materials, traces, or trackways. Geologic units with high potential also may include those that contain datable organic remains older than late Holocene (e.g., animal nests or middens). These units include, but are not limited to, sedimentary formations that contain significant nonrenewable paleontological resources anywhere within their geographical extent and sedimentary rock units temporally or lithologically suitable for the preservation of fossils. These units may also include some volcanic and low-grade metamorphic rock units. Fossiliferous deposits with very limited geographic extent or an uncommon origin (e.g., tar pits and caves) are given special consideration and ranked as highly sensitive. A unit with high sensitivity is susceptible to surface-disturbing activities and includes fossiliferous sedimentary deposits that are well exposed with little vegetative cover as well as those shallowly covered by soil, alluvium, or vegetation.

Sources: Caltrans 2017; SVP 2010
Caltrans = California Department of Transportation
N/A = not applicable
SVP = Society of Vertebrate Paleontology

Method for Evaluating Impacts under NEPA

CEQ NEPA regulations (40 C.F.R. Parts 1500–1508) provide the basis for evaluating project effects (as described in Section 3.1.5.4). As described in Section 1508.27 of these regulations, the criteria of context and intensity are considered together when determining if a project action would affect a resource.

- **Context**—For this analysis, the *context* would be the likelihood that fossils would be encountered during ground disturbance, in combination with the probability that the affected fossils are scientifically important. For example, damage or destruction as the result of surface and subsurface disturbance, as well as loss to the scientific community through vandalism or unauthorized collection of a scientifically important fossil or fossils, would be an impact.

- **Intensity**—Paleontological resources are nonrenewable, and any loss because of direct or indirect impacts results in the permanent unavailability of the fossil specimen and associated data to scientific research and education, as well as the loss of the information about Earth's history that it could have potentially provided.

Method for Determining Significance under CEQA

For this analysis, the project would result in a significant impact on paleontological resources if it would directly or indirectly destroy a unique paleontological resource or site or unique geologic feature.

3.9.5 Affected Environment

This section describes the affected environment for geology, soils, seismicity, and paleontological resources in the RSA. This information provides the context for the environmental analysis and the evaluation of impacts for the project alternatives.

3.9.5.1 Physiography and Regional Geologic Setting, Geologic Conditions, and Soils

Physiography and Regional Geologic Setting

The RSA is in the Coast Ranges geomorphic province, which consists of a series of generally northwest-southeast-oriented mountain ranges and alluvial filled valleys approximately parallel to the central California coast and the San Andreas fault system. A *geomorphic province* is a region of unique topography and geology that is readily distinguished from other regions based on its landforms and tectonic history. The Coast Ranges province owes much of its physiographic character to the San Andreas fault system, where two adjoining tectonic plates that form the Earth's surface—the Pacific Plate on the west and the North American Plate on the east—are moving past each other in opposite directions. The Coast Ranges bedrock generally consists of Mesozoic igneous, metamorphic, and marine sedimentary rocks overlain by Cenozoic marine and nonmarine sedimentary rocks. These geologic units have been faulted, folded, and altered by tectonic processes related to ancient subduction and current transverse tectonic plate movements.

The RSA is situated along the San Francisco peninsula, which separates San Francisco Bay from the Pacific Ocean. The San Francisco peninsula is a ridge of rock and sediments that forms a rugged barrier between the Pacific Coast and inland California. The RSA lies on the east side of the San Francisco peninsula, occupying mostly flatlands, which consist mainly of alluvial sediments along the west margin of San Francisco Bay. South and east of the San Francisco peninsula, the RSA is situated in the Santa Clara Valley. The Santa Clara Valley is part of a structural trough bounded by the Santa Cruz Mountains to the west and the Diablo Range to the east, extending approximately 90 miles southwest from San Francisco (U.S. Geological Survey [USGS] 1990). The Santa Clara Valley has been filled by Quaternary-age sediments derived from the surrounding mountains, resulting in broad coalescing alluvial fans, fan levees, and inter-levee basins (USGS and CGS 2006).

Topography near the RSA is characterized by gentle topographic relief in alluvial areas and steeper topography in regions controlled by bedrock. The topography typically slopes downward to the east toward the San Francisco Bay. The ground surface elevation near the project footprint ranges from approximately 10 to 220 feet; however, the existing Caltrain corridor elevation has only minor elevation changes and maintains gentle slopes by using earthwork cuts, fills, and tunnels.[4] Depth to groundwater in the RSA is variable within the various geologic and topographic terrains and is discussed further in Shallow Groundwater in Section 3.9.5.2, Geologic Hazards.

The RSA is in a seismically active region of California with known active surface faulting and historic earthquakes. This seismicity is a result of the progressive southeastern movement of the

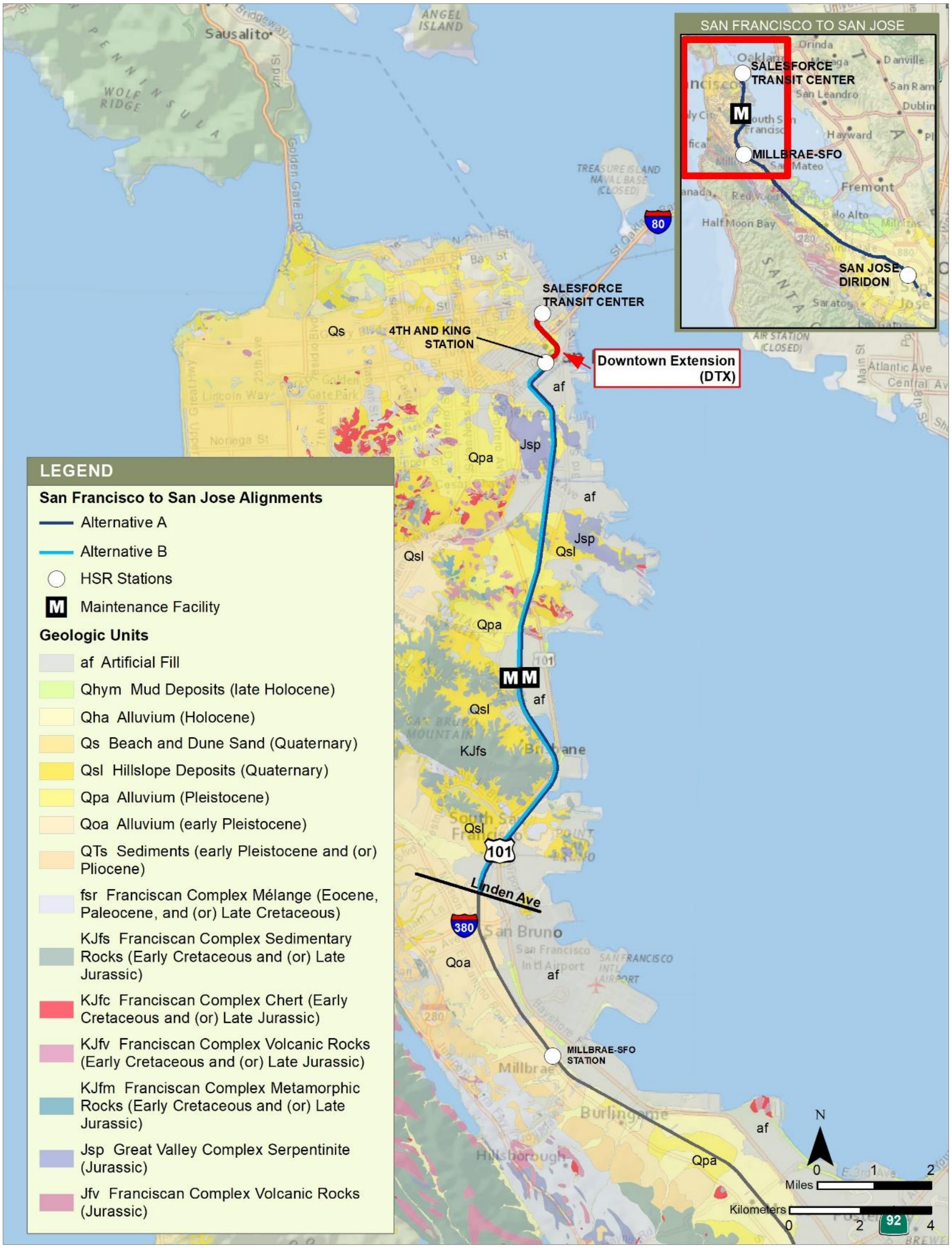
[4] Elevations are based on USGS topographic maps (USGS 2012, 2015b, 2018a, 2018b, 2018c, 2018d, 2018e, 2018f) and Google Earth, using the datum WGS84.

North American tectonic plate relative to the Pacific tectonic plate. At the approximate latitude of the RSA, the Pacific plate moves about 38 millimeters per year relative to the North American tectonic plate (Authority and FRA 2017c, 2017d). Seismic hazards are discussed in additional detail in Section 3.9.5.3, Primary Seismic Hazards.

Geologic Conditions

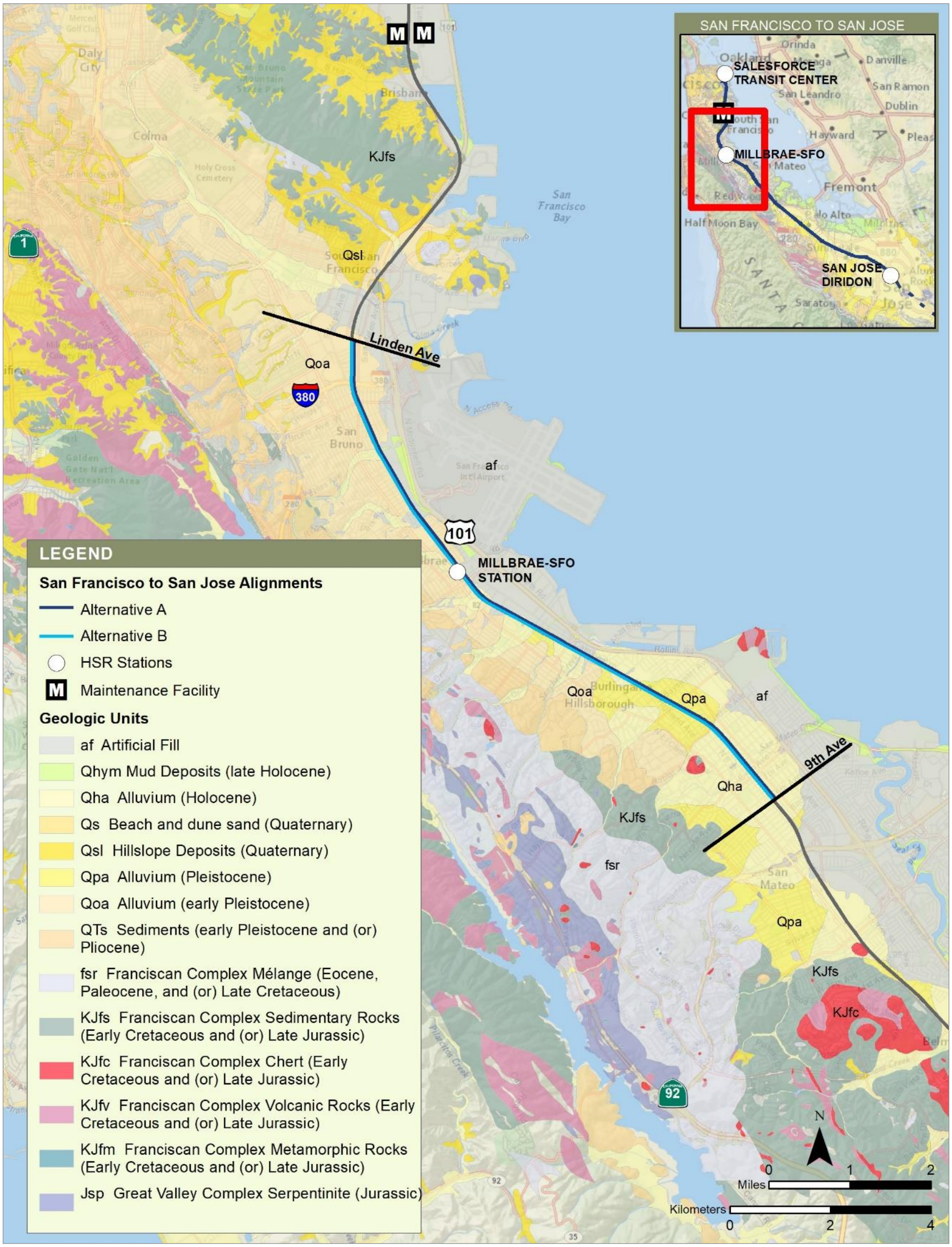
The geology of the San Francisco Bay Area (Bay Area) has been extensively mapped (California Division of Mines and Geology [CDMG] 1969, 1991; CGS 2010a; Dibblee and Minch 2007a, 2007b; Hitchcock and Helley 2003; USGS 1968, 1983, 1993, 1994, 1995, 1998a, 1998b, 1999a, 2000a, 2000b, 2006a). In general, Holocene (11,700 years to present) and Pleistocene (1.8 million years to 11,700 years) alluvial deposits occur throughout the flatlands of the San Francisco Peninsula and Santa Clara Valley, while Mesozoic (65 to 248 million years) bedrock make up the mountains west of the alignment. Figure 3.9-1 through Figure 3.9-5 illustrate the geologic units mapped near the RSA. Table 3.9-4 provides a summary of the geologic units and identifies their distribution by subsection. The mapped geologic conditions within each subsection are:

- **San Francisco to South San Francisco Subsection**—Artificial fill underlain by Holocene Bay Mud and Pleistocene alluvium in low-lying areas. Cretaceous and Jurassic Franciscan complex sedimentary rocks and serpentinite in upland areas such as Potrero Hill, Silver Terrace, Visitacion Valley, and San Bruno Mountain (USGS 2006a).
- **San Bruno to San Mateo Subsection**—Pleistocene and Holocene alluvium with some areas of artificial fill underlain by Holocene Bay Mud near San Francisco International Airport, Millbrae, and Burlingame (USGS 2006a).
- **San Mateo to Palo Alto Subsection**—Pleistocene and Holocene alluvium with some areas of artificial fill underlain by Holocene Bay Mud near San Mateo and Belmont. Cretaceous and Jurassic Franciscan complex sedimentary rocks and chert in upland areas near Belmont (USGS 2006a).
- **Mountain View to Santa Clara Subsection**—Mostly Holocene alluvium with some Pleistocene alluvium near Ponderosa Park (USGS 2006a).
- **San Jose Diridon Station Approach Subsection**—Holocene alluvium (USGS 1999a).



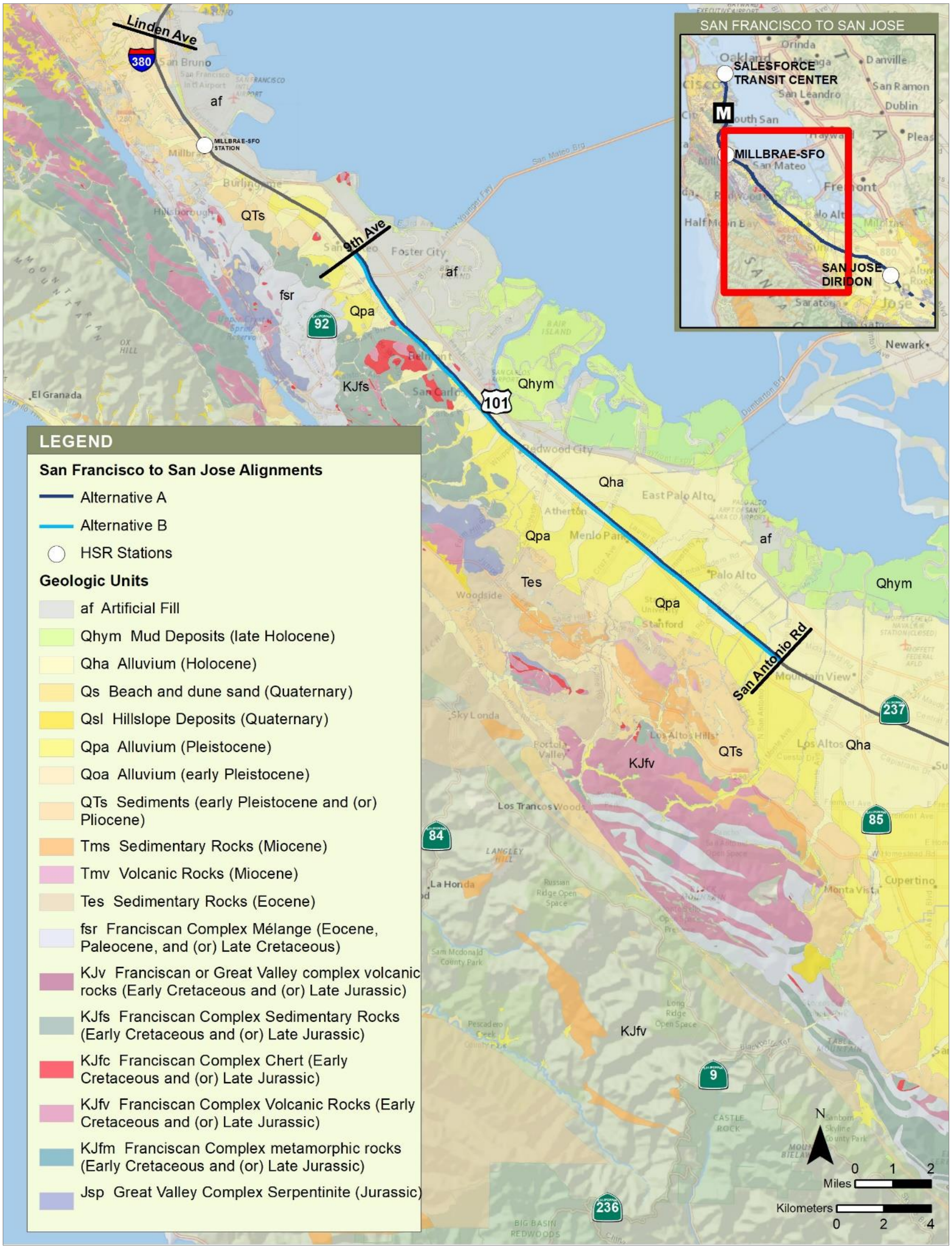
Source: USGS 2006a MAY 2019

Figure 3.9-1 Geologic Map—San Francisco to South San Francisco Subsection



Source: USGS 2006a MAY 2019

Figure 3.9-2 Geologic Map—San Bruno to San Mateo Subsection



Source: USGS 2006a

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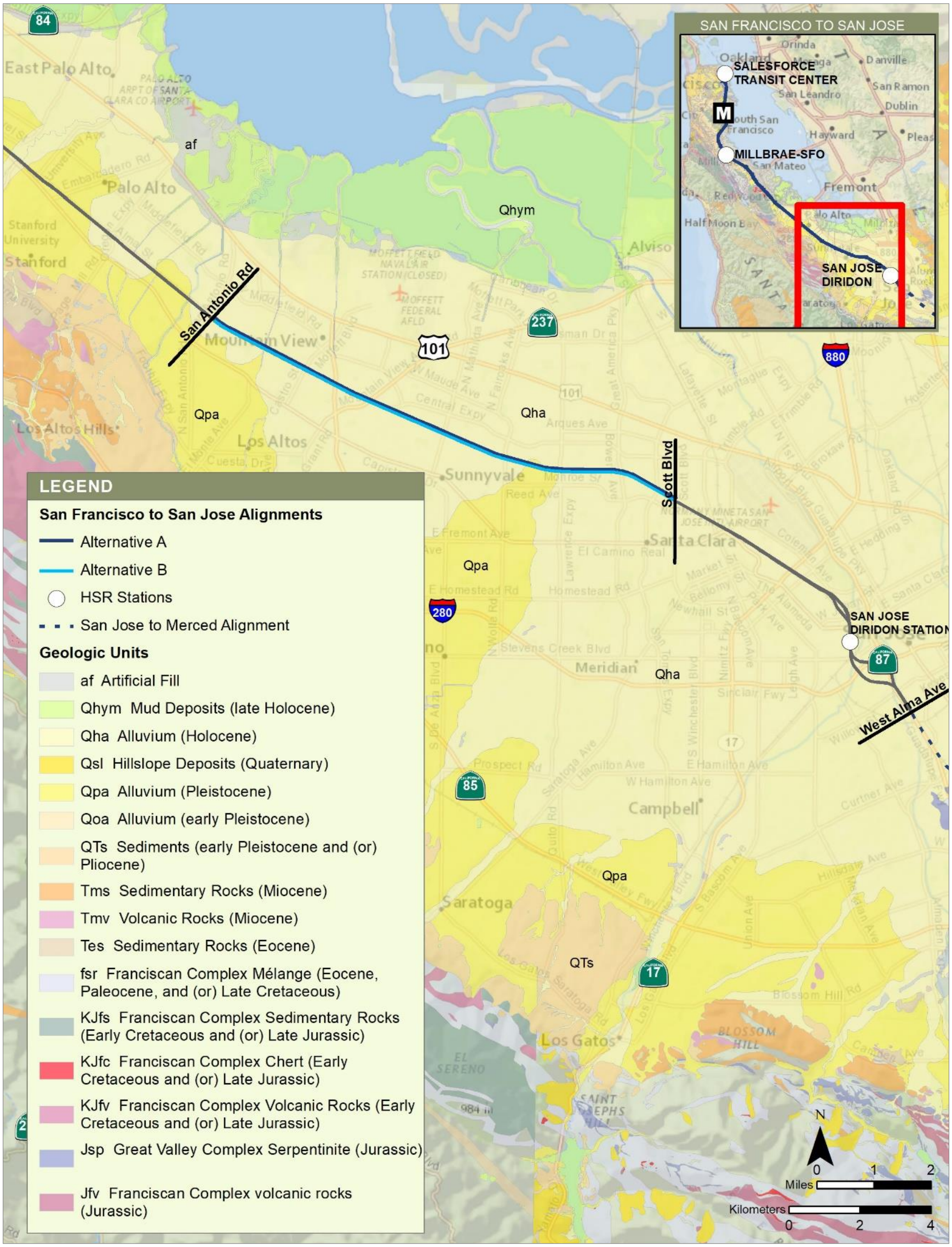
Figure 3.9-3 Geologic Map—San Mateo to Palo Alto Subsection



Source: USGS 2006a

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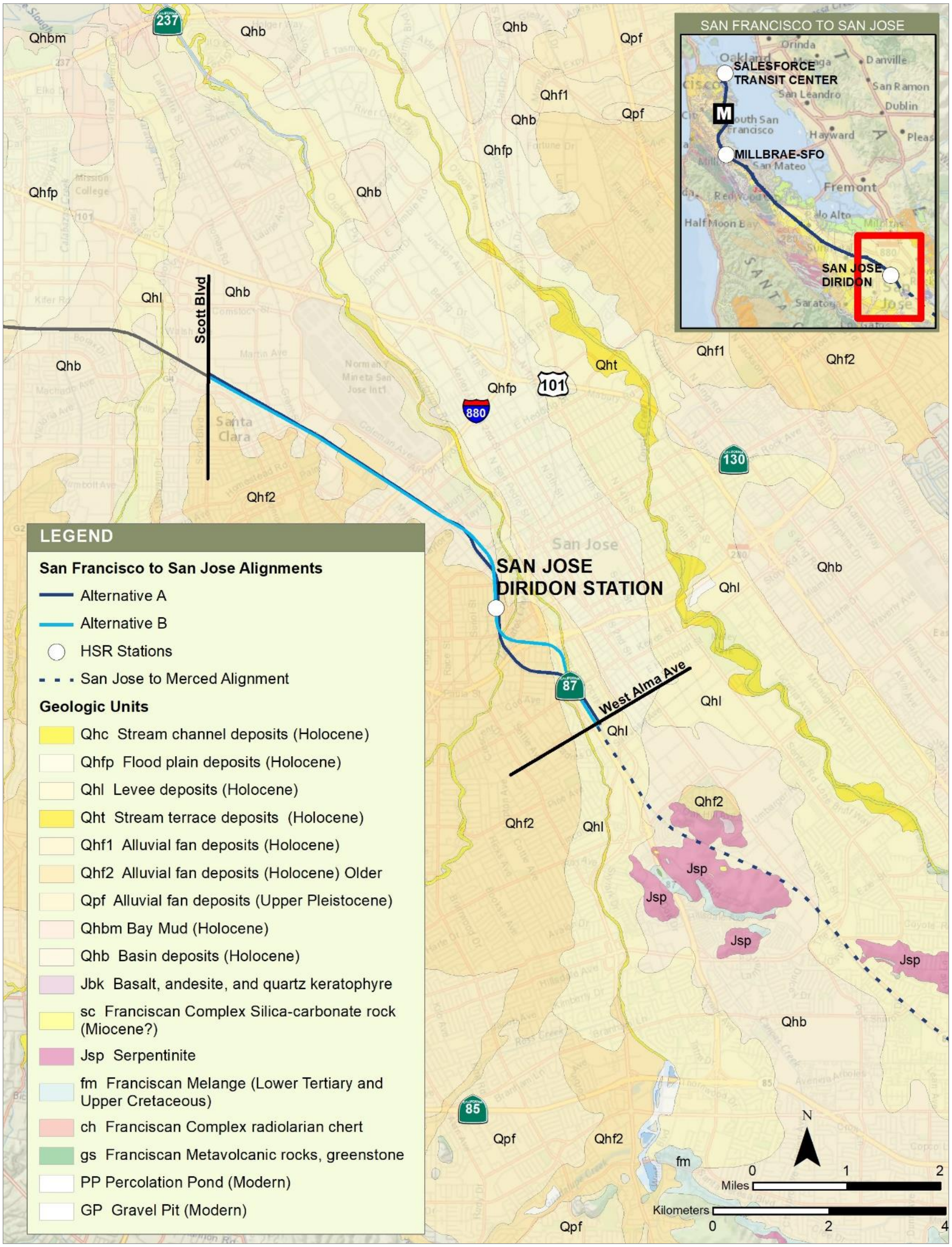
Figure 3.9-4 Geologic Map—Mountain View to Santa Clara Subsection



Source: USGS 2006a

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Figure 3.9-5 Geologic Map—San Jose Diridon Station Approach Subsection

Table 3.9-4 Summary and Distribution of Geologic Units throughout Resource Study Area

Geologic Deposit	Geologic Unit Type	Description	Presence by Subsection				
			San Francisco to South San Francisco	San Bruno to San Mateo	San Mateo to Palo Alto	Mountain View to Santa Clara	San Jose Diridon Station Approach
Artificial Fill (af)	N/A	Imported fill over native soil deposits in areas that were historically reclaimed shallow bay and marshlands adjacent to the San Francisco Bay; variable type and consistency.	X	X	X	X	
Bay Mud (Qhym)	Holocene	Generally mapped below the fill along former shoreline and marshes along the San Francisco Bay that have been filled. Bay Mud consists of saturated, highly organic, highly plastic silty clay or clayey silt. Bay Mud is very soft to soft and highly compressible. The upper portion of the deposit (Young Bay Mud) is very soft and is only capable of supporting light to moderate structural loads after it has been dewatered, compressed, or hardened. The lower portion (Old Bay Clay) is capable of supporting moderate to heavy structural loads, if properly engineered.	X				
Alluvium (Qha)	Holocene	Alluvial fan and fluvial deposits—Gravelly sand or sandy gravel that generally grades upward to sandy or silty clay. Floodplain deposits—Sandy to silty clay with lenses of coarser material (silt, sand, and pebbles) may be locally present. Floodplain deposits usually occur between levee deposits and basin deposits.	X	X	X	X	
Basin Deposits (Qhb)	Holocene	Alluvial deposits that consist of sandy and clayey silt ranging to sandy and silty clay, loose and moderately to well sorted.					X
Levee Deposits (Qhl)	Holocene	Alluvial deposits that consist of sandy and clayey silt ranging to sandy and silty clay, loose and moderately to well sorted. These deposits are associated with the Guadalupe River and Coyote Creek and other present day drainages.					X

Geologic Deposit	Geologic Unit Type	Description	Presence by Subsection				
			San Francisco to South San Francisco	San Bruno to San Mateo	San Mateo to Palo Alto	Mountain View to Santa Clara	San Jose Diridon Station Approach
Stream Terrace Deposits (Qht)	Holocene	Alluvial deposits located low in the local topography along the Guadalupe River and Los Gatos Creek channels consisting of unconsolidated moderately to poorly sorted sand, gravel, silt, and clay.					X
Alluvial Fan Deposits, older (Qhf_2)	Holocene	Alluvial deposits derived from the Santa Cruz Mountains to the west that consist of sandy and clayey silt ranging to sandy and silty clay, loose and moderately to well sorted.					X
Beach and Dune Sand (Qs)	Quaternary	Colma Formation—Pleistocene formation composed of fine- to medium-grained sand with minor amounts of sandy silt, clay, and gravel as interbeds.	X				
Hillslope Deposits (Qsl)	Quaternary	Slope debris or ravine fill—Silty to sandy clay, silty to clayey gravel, unstratified to poorly stratified.	X				
Alluvium (Qpa)	Pleistocene	Older alluvial fan and fluvial deposits—Gravelly and clayey sand or clayey gravel that fines upward to sandy clay. These deposits display variable sorting and are located along most modern stream channels. They are distinguished from younger alluvial fans and fluvial deposits by higher topographic position, greater degree of dissection, and stronger soil profile development.	X	X	X	X	
Alluvium (Qoa)	Early Pleistocene		X	X			
Franciscan Complex Melange (fsr)	Eocene, Paleocene, and/or Late Cretaceous	Sandstone—Fine to coarse-grained greywacke sandstone with interbedded siltstone and shale. In many places, shearing has obscured bedding relations. Greenstone—Blocks or slabs of greenstone within the melange. Chert—Chert, in places interbedded with shale. Chert and shale commonly are rhythmically banded in thin layers, but chert also crops out in very thick layers.	X				

Geologic Deposit	Geologic Unit Type	Description	Presence by Subsection				
			San Francisco to South San Francisco	San Bruno to San Mateo	San Mateo to Palo Alto	Mountain View to Santa Clara	San Jose Diridon Station Approach
Franciscan Complex Sedimentary Rocks (KJfs)	Early Cretaceous and/or Late Jurassic	Sandstone and shale—Cretaceous and Jurassic Sandstone and Shale is encountered beneath Bay Mud and Colma Formation. These units consist of interbedded greywacke sandstone and shale bedrock that has been folded and faulted to create localized zones of highly sheared rock.	X		X		
Franciscan Complex Chert (KJfc)	Early Cretaceous and/or Late Jurassic	Chert, in places interbedded with shale. Chert and shale commonly are rhythmically banded in thin layers, but chert also crops out in very thick layers.			X		
Franciscan Complex Volcanics (KJfv)	Early Cretaceous and/or Late Jurassic	Greenstone—Altered volcanic rocks, fine grained, mostly basalt.	X				
Great Valley Complex Serpentinite (Jsp)	Jurassic	Serpentinite—Sheared serpentinite composes most of Potrero Hill, including variably abundant blocks of unsheared rock; blocks are commonly smaller than 3 meters in largest dimension but range from several centimeters to several meters.	X				

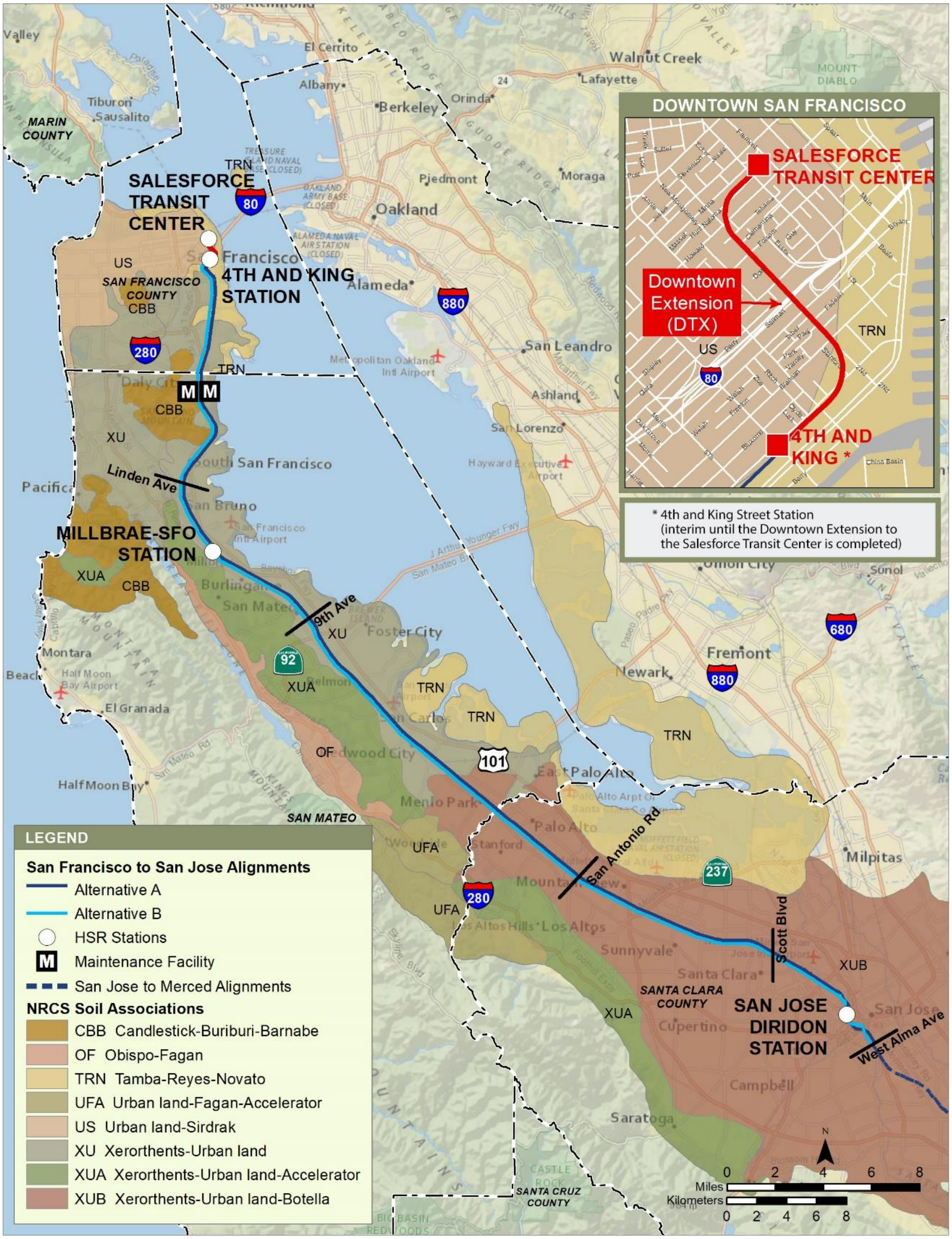
Sources: USGS 1983, 1994, 1998a, 1998b, 1999a, 2000a, 2006a; CGS 2010a; CDMG 1969, 1991
N/A = not applicable

Soils

Soils are composed of mineral grains and organic matter that have developed on the Earth's surface. Typical engineering properties of soil considered for design and construction of structures include shrink-swell potential, density/consistency, moisture content, shear strength, compressibility, erosion potential, cementation, and corrosion potential. Engineering properties and behavior differ between soil types; for example, some soils are hard and strong, while others are soft and weak. The United Soil Classification System (USCS) is a commonly used geotechnical engineering standard (American Society for Testing and Materials [ASTM] D2487) (ASTM 2011) for classifying soils into categories based on the results of prescribed laboratory tests to determine properties such as the particle size distribution, the liquid limit, and plasticity indices.

The RSA extends along the margin of San Francisco Bay, which consists of tidal flats and estuaries that have been filled artificially during the last 160 years. Young Bay Mud underlies much of the artificial fill; it is not always mapped at the ground surface. The lowlands west of the tidal flats are primarily composed of alluvial soils derived from the surrounding hills and mountains to the west. These alluvial soils are typically composed of mixtures of gravel, sand, silt, and clay.

Since the 1930s, various government agencies and universities have conducted soil mapping, emphasizing a soil's agricultural and engineering properties. The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) soil surveys (USDA-NRCS n.d.) describe soil units in the RSA, including basic engineering properties and USCS soil classifications. A soil association mapped by the NRCS is made up of two or more geographically associated soils that are grouped together for the practicality of mapping (USDA-NRCS n.d.). This information is based on conditions within 4 to 5 feet of the ground surface. Figure 3.9-6 illustrates the soil associations in the RSA, which are primarily some form of urban land. These are urban areas where NRCS could not map the surficial soil because of human development. Table 3.9-5 provides a summary of the physiographic features, soil associations, and soil hazards for each soil association in the RSA.



Source: USDA-NRCS n.d.

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Figure 3.9-6 Natural Resources Conservation Service Soil Associations

Table 3.9-5 Association Characteristics throughout the Geology, Soils, and Seismicity Resource Study Area

Soil Association (Map Symbol)	Soil Textures	Subsection	Landform Groups[1]	Soil Hazards
Tamba-Reyes-Novato (TRN)	Mucky clay, silty clay loam, silty clay, clay	San Francisco to South San Francisco	Mixed alluvial and hydrophytic plant remains	▪ Moderate to high shrink-swell potential ▪ Moderately to highly corrosive to uncoated steel ▪ Moderately to highly corrosive to concrete ▪ Susceptible to erosion ▪ Moderate potential for water erosion ▪ Moderate potential for wind erosion
Xerorthents-Urban land (XU)	Clay loam to silty clay loam, sandy clay loam	San Francisco to South San Francisco San Bruno to San Mateo San Mateo to Palo Alto	Recent alluvial fans and flood plains	▪ Low to moderate shrink-swell potential ▪ Moderately to highly corrosive to uncoated steel ▪ Slightly corrosive to concrete ▪ Medium to coarse texture soils susceptible to erosion ▪ Moderate potential for water erosion ▪ High potential for wind erosion
Candlestick-Buriburi-Barnabe (CBB)	Loam, sandy loam, sandy clay loam, gravelly loam	San Francisco to South San Francisco	Formed in residuum weathered from hard sandstone, siltstone, and shale	▪ Low to moderate shrink-swell potential ▪ Moderately to highly corrosive to uncoated steel ▪ Moderately corrosive to concrete ▪ Medium to coarse texture soils susceptible to erosion ▪ Moderate potential for water erosion ▪ High potential for wind erosion
Xerorthents-Urban land-Accelerator (XUA)	Clay loam to silty clay loam, sandy clay loam, loam, gravelly clay loam	San Mateo to Palo Alto	Recent alluvial fans and flood plains	▪ Low to moderate shrink-swell potential ▪ Moderately to highly corrosive to uncoated steel ▪ Slightly corrosive to concrete ▪ Medium to coarse texture soils susceptible to erosion ▪ Moderate potential for water erosion ▪ High potential for wind erosion

Soil Association (Map Symbol)	Soil Textures	Subsection	Landform Groups[1]	Soil Hazards
Xerorthents-Urban land-Botella (XUB)	Clay loam, silty clay loam, sandy clay loam	San Mateo to Palo Alto Mountain View to Santa Clara San Jose Diridon Station Approach	Recent alluvial fans and flood plains	▪ Low to moderate shrink-swell potential ▪ Moderately to highly corrosive to uncoated steel ▪ Moderately corrosive to concrete ▪ Medium to coarse texture soils susceptible to erosion ▪ Moderate potential for water erosion ▪ High potential for wind erosion

Source: USDA-NRCS n.d.
NRCS = Natural Resources Conservation Service
USDA = U.S. Department of Agriculture
[1] As mapped by USDA-NRCS, not necessarily observed in the geology, soils, and seismicity resource study area.

3.9.5.2 Geologic Hazards

Geologic hazards (also called geohazards) are hazards resulting from adverse rock or soil conditions that are capable of causing damage or loss of life. Geologic hazards include ground subsidence, landslides, soft soil, expansive soils, soil erosion, shallow bedrock, shallow groundwater, and landfill gas and refuse. The following sections discuss these geologic hazards.

Ground Subsidence

Ground subsidence is the settling or sinking of the land surface. In the region, subsidence is caused by groundwater extraction from alluvial geologic formations. Subsidence can happen over large areas when it results from regional groundwater extraction or over small areas when it results from localized dewatering.

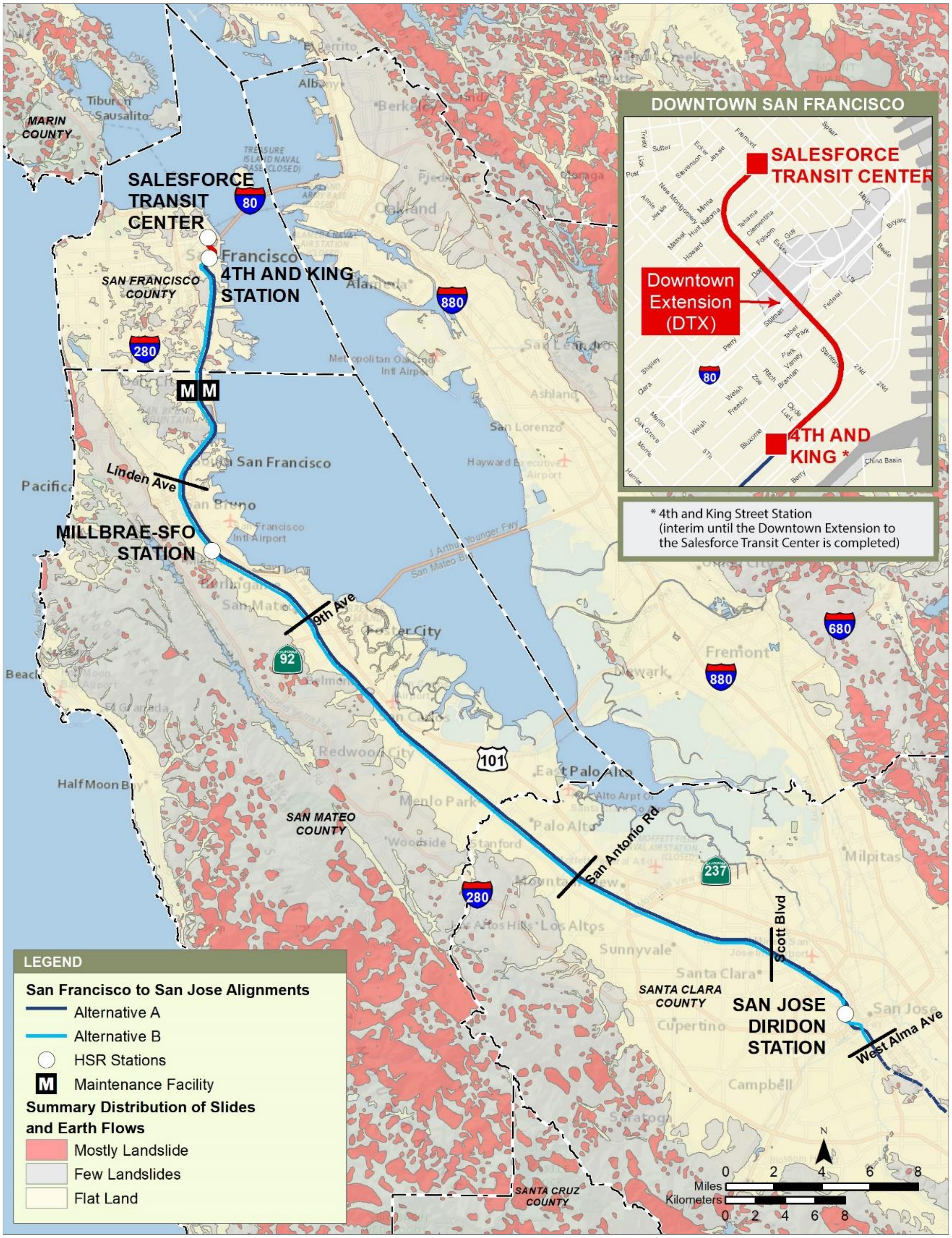
Regional subsidence has not been observed in San Francisco and San Mateo Counties, but has been observed historically in the Santa Clara Valley, as far north as Palo Alto. Historical subsidence in the Santa Clara Valley within the Mountain View to Santa Clara and San Jose Diridon Station Approach Subsections is caused by groundwater pumping that resulted in up to approximately 14 feet of settlement from 1915 to 1970 (Borchers and Carpenter 2014). Since 1970, reduced groundwater pumping and a groundwater recharge program using imported surface water has allowed an effective program of groundwater recharge that prevents groundwater levels from approaching the historic lows of the 1960s. Artificial recharge rates in the 1970s were sufficient to reverse groundwater level declines and arrest subsidence (USGS 1999b). The Santa Clara Valley Water District provides ongoing monitoring of benchmarks on the land surface, subsurface extensometers, and groundwater levels at subsidence index wells to determine if land subsidence is occurring or threatening to exceed a threshold of 0.01 foot per year. The 2017 subsidence monitoring from Santa Clara Valley Water District reports a low risk of subsidence (Santa Clara Valley Water District 2017).

Under the Sustainable Groundwater Management Act, medium- and high-priority groundwater basins should reach sustainability, by balancing pumping and recharge levels, by 2042 (California Department of Water Resources 2018a, 2018b). The alignment passes through two medium-priority groundwater basins—the Westside Groundwater Basin and the Santa Clara Valley Groundwater Basin. Balancing levels of aquifer pumping and recharge would significantly reduce or eliminate potential for regional ground subsidence within a basin.

Different from regional ground subsidence, localized subsidence is caused by small-scale dewatering associated with construction of below-grade facilities in areas with shallow groundwater. Substantial portions of the project alignment have groundwater resources present within 20 feet of the ground surface, which may require construction dewatering, as discussed in more detail under Shallow Groundwater.

Landslides

Landslides are the downhill movements of soil or rock along shear surfaces. Landslides can lead to ground deformation and debris flows that can cause damage to structures and be hazardous to people. The best available predictor of where movement of landslides might occur is the distribution of past movements (USGS 1975). Because of the relatively flat topography in the majority of the RSA, most of the area has little or no potential for landslides. The few areas with such potential are in the San Francisco to South San Francisco Subsection where the alignment is near steep slopes. The alignment passes through existing tunnels in Potrero Hill, Mount St. Joseph, and Visitacion Valley, which are mapped as areas with the potential for landslides. The tunnels are not susceptible to landslides, and the proposed alternatives would not require excavating at the existing portals. Near Brisbane, where the alignment skirts around the east side of San Bruno Mountain, the alignment crosses limited areas mapped as “few landslides” and “mostly landslides” and one small area of “few landslides” in South San Francisco. These areas have some potential for landslides. Figure 3.9-7 illustrates the geographic distribution of landslides and earth flows near the RSA as mapped by USGS (1997).



Source: USGS 1997 MAY 2019

Figure 3.9-7 Summary Distribution of Slides and Earth Flows

Additional details regarding landslides are discussed in the San Francisco to San Jose Geology, Soils, and Seismicity Technical Report, Section 5.2.2, Landslides (Authority 2019a) and in the San Jose to Merced Geology, Soils, and Seismicity Technical Report, Section 5.2.3, Landslides (Authority 2019b).

Soft Soil

Soft soil generally consists of relatively young, fine-grained soil (clay and silt) layers that are compressible, weak (low shear strength), and potentially unstable. Soft soil can compress under new loads, resulting in ground settlement that can damage structures. The settlement could extend beyond the footprint of a new load, which could cause damage to adjacent structures. The magnitude of compression of soft soil is related to the thickness of the soft soil layer, the new load, the distance between the application of the load and the soft soil layer, and other characteristics of the soil. Because soft soil has a low shear strength, it can exhibit slope instability, impede earthwork operations, and make soil compaction difficult.

The fringes of the San Francisco Bay are underlain by soft, compressible clayey silt to silty clay, known as Young Bay Mud. Locations with thicker deposits of Young Bay Mud have a potential for significant settlement under new construction loads. Structures built upon Young Bay Mud are susceptible to potentially large consolidation settlement and must be able to accommodate or avoid such deformation. Furthermore, the low strength of Young Bay Mud may not support new construction loads resulting in bearing capacity failures. Parts of San Francisco and the former tidal flats along the eastern edge of the San Francisco Peninsula have been filled artificially during the last 160 years. Young Bay Mud underlies much of the artificial fill, which means that it is not always visible or mapped at the ground surface. Young Bay Mud thicknesses are estimated underlying various portions of the alignment, as depicted on Figure 3.9-8. The thickest deposits of Young Bay Mud occur within the San Francisco to South San Francisco Subsection and the thickness generally decreases from north to south along the Project Section. Additional details regarding soft soils are discussed in the San Francisco to San Jose Geology, Soils, and Seismicity Technical Report, Section 5.2.3, Soft Soils (Authority 2019a) and the San Jose to Merced Geology, Soils, and Seismicity Technical Report, Section 5.2.4, Soft Soils (Authority 2019b).

Expansive Soil

Expansive soil is soil that changes in volume with changes in moisture content. Expansive soil can shrink or swell and cause differential movement and damage to surface improvements. Soils are generally categorized as having low, moderate, or high expansive potential; the type and percentage of clay particles in the soil influence the soil's expansion potential. Generally, predominantly fine-grained soils containing a high percentage of clay are expansive, whereas predominantly coarse-grained soils such as sands and gravels are generally not expansive.

Based on the regional geology, soil types, and review of existing borehole data (CGS n.d.; Authority and FRA 2017b), areas of expansive soil would likely be encountered within most of each subsection. Alluvial deposits, fill, and Bay Mud are the dominant mapped geologic units along the alignment. Alluvial deposits commonly contain intermittent near-surface clay layers that can be expansive. Bay Mud is primarily composed of expansive clay. Also, because fill is generally locally sourced, it is likely composed of mixtures of alluvium and Bay Mud and therefore is likely to contain expansive soil. Additionally, mapped NRCS soil associations Tamba-Reyes-Novato and Xerorthents-Urban land-Botella are described as including soil with moderate to high shrink-swell potential.

Corrosive Soil

Soils can be corrosive to buried concrete and steel and can lead to premature degradation and failure of concrete and steel structures. Moderately to highly corrosive soil would likely be encountered in all subsections as depicted on Figure 3.9-9 (USDA-NRCS n.d.). Note that much of the alignment in urban areas is mapped as "no data," which does not preclude the presence of moderate or high corrosion areas.

Source: CDMG 1969

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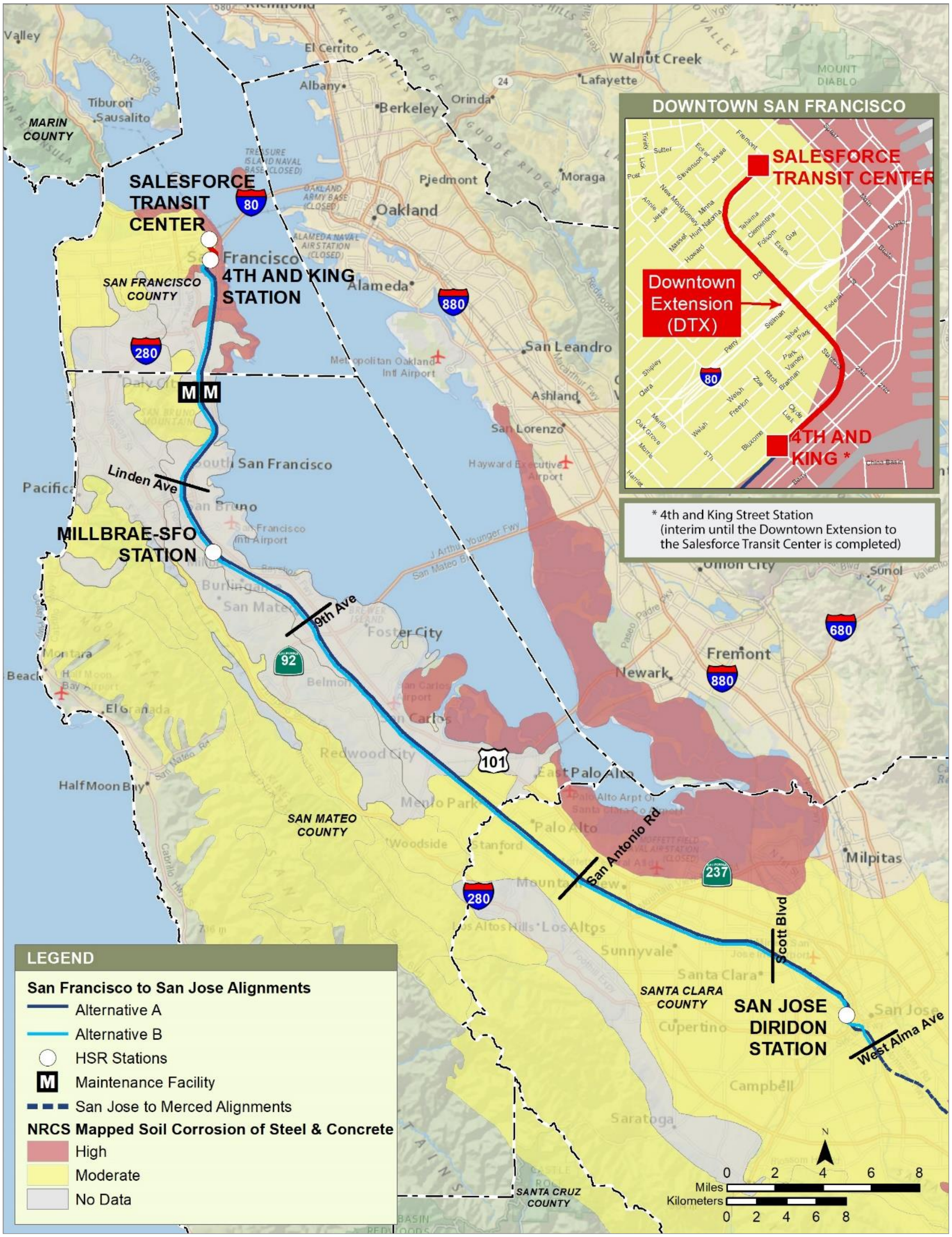
Figure 3.9-8 Thickness of Young Bay Mud



Source: USDA-NRCS n.d.

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Figure 3.9-9 Soil Corrosion of Concrete and Steel

Soil Erosion

Soil erosion is the action of surface processes, such as water flow and wind, that transport soil and rock particles from one location to another. Factors that affect soil erosion potential include soil type, soil moisture, rainfall, ground cover, surface water flow, wind speed, and topography. Most of the RSA is susceptible to soil erosion because all soil types in the RSA are characterized by moderate to high potential for wind or water erosion, as shown in Table 3.9-5 (USDA-NRCS n.d.).

Shallow Bedrock

Shallow bedrock can be difficult to excavate with conventional machinery and may require the use of more dangerous excavation methods or equipment. Deeper excavations are more likely to encounter harder rock that requires potentially more dangerous methods because the degree of weathering typically decreases with depth and the strength typically increases. In some cases, explosives may be required to blast bedrock that cannot be excavated with machinery.

Most of the RSA is in areas of alluvium with no shallow bedrock. The project alternatives would cross limited areas of shallow bedrock; however, the project alternatives would use the existing Caltrain corridor and therefore generally would not involve significant new excavation. The risk of encountering shallow bedrock is expected to be limited to relatively small areas in the San Francisco to South San Francisco and San Mateo to Palo Alto Subsections. In these subsections, topographically higher areas such as Potrero Hill, San Bruno Mountain, and the area near Belmont are mapped as Cretaceous and Jurassic bedrock, as illustrated on Figures 3.9-1 through 3.9-5 (USGS 2006a).

Shallow Groundwater

Shallow groundwater can make construction excavations less stable, and necessitate dewatering during construction. Unstable excavations can lead to increased safety hazards for construction workers. Shallow groundwater is typically encountered in low-lying valleys and basins where the groundwater elevation is similar to the ground surface elevation. Groundwater within all subsections is generally within 20 feet of the ground surface, and follows the east and northward trend of the ground surface elevation toward the San Francisco Bay. Additional details regarding shallow groundwater, including measurement data collected through previous subsurface exploration programs, are discussed in the San Francisco to San Jose Geology, Soils, and Seismicity Technical Report, Section 5.2.9, Shallow Groundwater (Authority 2019a) and San Jose to Merced Geology, Soils, and Seismicity Technical Report, Section 5.2.12, Shallow Groundwater (Authority 2019b).

Landfill Gas and Refuse

Landfills are designated locations where refuse is buried. When the organic material in a landfill decomposes, it produces a byproduct called landfill gas. Landfill gas is composed of methane, carbon dioxide, and a small amount of non-methane organic compounds. The methane in landfill gas is flammable and can become a hazard if released. Landfills can also be a hazard because of the compressibility of the buried refuse. Structures that add additional weight on top of the landfill can cause the buried refuse to compress, resulting in ground settlement that could damage the structures. The decomposition of organic refuse can also cause long-term ground settlement.

The former Brisbane Landfill is within the RSA in the San Francisco to South San Francisco Subsection. The landfill is between U.S. Highway 101 and the Caltrain alignment in Brisbane. The landfill is approximately 364 acres in area and was operated as a waste disposal site from 1932 to 1967. The refuse varies in thickness from approximately 35 to 40 feet and sits directly on Young Bay Mud deposits (Geosyntec 2018).

3.9.5.3 Primary Seismic Hazards

Primary seismic hazards are hazards directly associated with earthquakes. The primary seismic hazards assessed in this analysis are surface fault ruptures transecting the alignment and ground shaking. The RSA is in a seismically active area where numerous small and large earthquakes have occurred in association with active faults. A seismic event, depending on the type of fault motion and exposure, can result in surface fault rupture—a permanent offset at the ground surface—and strong ground shaking.

The RSA is in a seismically active region of California where active and potentially active seismic faults are prevalent. Fault rupture is the relief of built-up stresses in the Earth resulting in rock or soil slipping past itself. Generally, fault rupture is abrupt and releases seismic energy in an event known as an earthquake. The seismic activity in the region is dominated by the right-lateral strike-slip, thrust, and reverse faults resulting from transpressional (strike-slip with a compressional component) plate motion of the North American tectonic plate relative to the Pacific tectonic plate (Authority and FRA 2017c, 2017d). The most prominent feature of this plate boundary is the right-lateral strike-slip San Andreas fault system that trends north-northwest across most of California (USGS 1990). The San Andreas fault is as close as 1.7 miles west of the alignment (CGS 2010b). East of the San Andreas fault, several other faults trending north-northwest exhibit right lateral movement and accommodate distributive slip from the tectonic plate boundary motion (USGS 1990). The more prominent of these faults in the Bay Area are the Hayward and Calaveras faults.

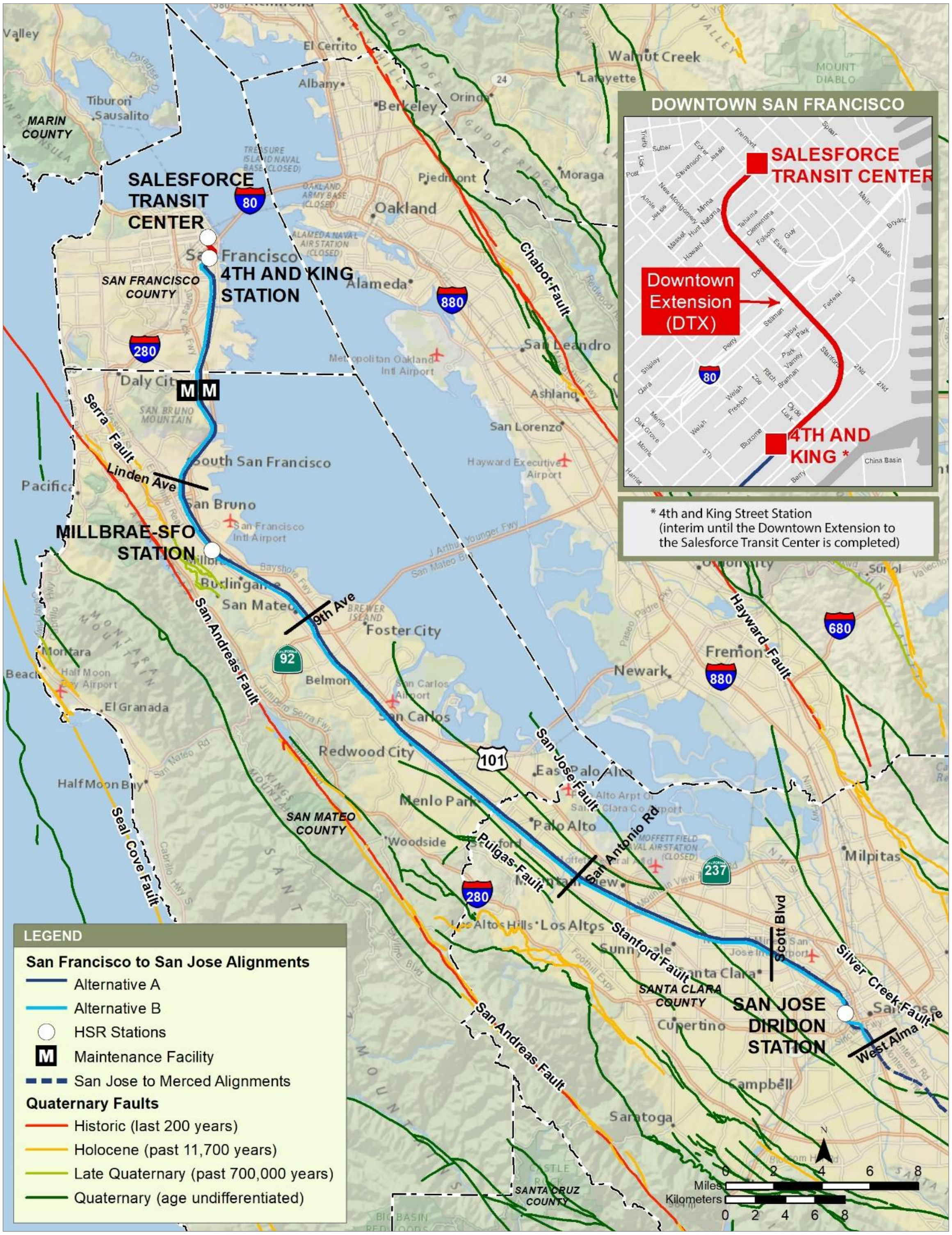
Figure 3.9-10 shows U.S. Geological Survey (USGS) mapped Quaternary-active faults (also referred to as Quaternary faults) close to the alignment. Quaternary faults are faults that have shown movement in Quaternary time (the last 1.6 million years) (CGS 2010b). As illustrated on Figure 3.9-10, the project is very near several Quaternary faults in several locations.

Surface Fault Rupture

Faults are planes of weakness in the Earth's crust where one side has moved relative to the other. When a fault ruptures, the energy released creates ground shaking known as an earthquake. Faults are recognized and mapped by sheared and displaced soil and/or rock units and by the distinctive landforms created by repeated rupture of the Earth's surface. Surface fault rupture refers to the extension of a fault to the ground surface in which the ground breaks, resulting in an abrupt relative ground displacement (e.g., vertical or horizontal offset). Surface fault ruptures can cause damage to structures within the rupture zone. Surface fault rupture hazards are typically associated with Holocene active faults identified and mapped by the CGS in accordance with the Alquist-Priolo Earthquake Fault Zoning Act. A Holocene active fault is a fault that has had surface displacement within the Holocene epoch, defined by CGS as the last 11,700 years (CGS 2018a). State-designated Special Studies Zones are within the RSA; the project alignment is only approximately 1.5 miles from the nearest Special Studies Zone (CDMG 1974a, 1974b, 1974c, 1974d, 1974e, 1982a, 1982b, 1982c, 1982d, 2000; CGS 2002a, 2002b, 2004a, 2004b, 2006a, 2006b, 2006c, 2006d). The project alignment does not cross any known Holocene active faults (USGS 2006b). The alignment does cross the San Jose fault in the Mountain View to Santa Clara Subsection and is near the Stanford fault in the San Mateo to Palo Alto Subsection. Additional details regarding surface fault rupture are discussed in the Geology, Soils, and Seismicity Technical Reports, Section 5.3.2, Surface Fault Rupture (Authority 2019a, 2019b).

Ground Shaking

The entire RSA is susceptible to ground shaking from a nearby earthquake. Ground shaking results from the sudden release of energy during an earthquake that creates seismic waves. These waves propagate through the Earth's crust and can damage engineered structures. Major earthquakes with the likelihood for causing significant damage or being felt for a large distance typically are at least a 6.0 on the moment magnitude scale. Relatively recent earthquakes with epicenters near the project alignment include the 1989 Loma Prieta (6.9 moment magnitude) and the 2014 South Napa (6.0 moment magnitude) earthquakes. Scientists have developed an earthquake forecast model for California referred to as the third Uniform California Earthquake Rupture Forecast (UCERF3). In the San Francisco region, the UCERF3 model predicts a 98 percent probability that one or more events with a magnitude greater than or equal to 6 will occur within the next 30 years (starting from 2014) (USGS 2015a). Additional details regarding ground shaking are discussed in the Geology, Soils, and Seismicity Technical Reports, Section 5.3.3, Ground Shaking (Authority 2019a, 2019b).



Source: USGS 2006b

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Figure 3.9-10 Quaternary Faults

3.9.5.4 Secondary Seismic Hazards

When strong ground shaking results from an earthquake, several secondary seismic hazards can occur. These hazards include liquefaction, lateral spreading, earthquake-induced landslides or slumps, and earthquake-induced flooding.

Liquefaction

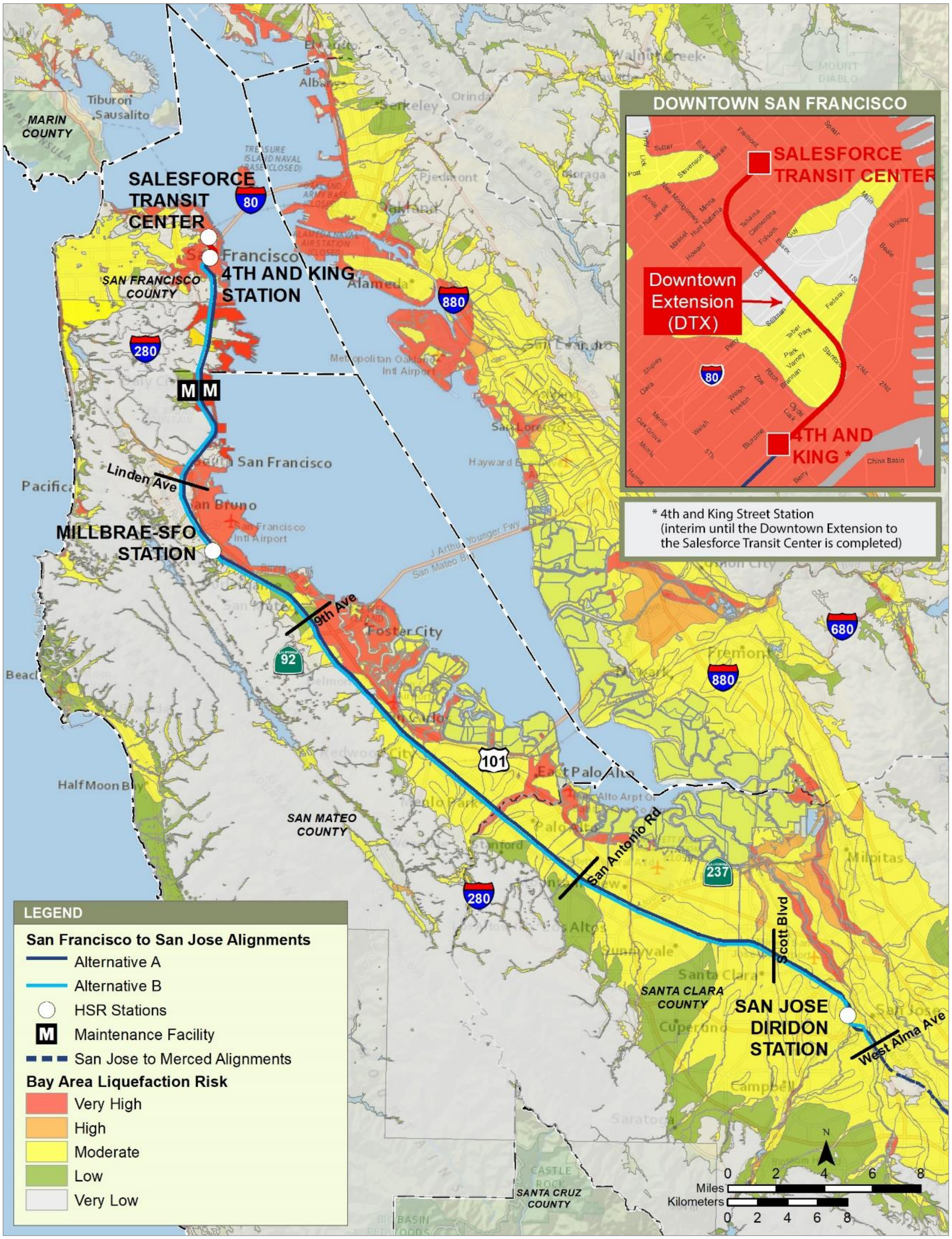
Soil liquefaction results from loss of strength during cyclic loading (application of repeated reversed forces), such as that imposed by earthquakes. Soils most susceptible to liquefaction are clean, loose, saturated, uniformly graded fine sands below the groundwater table. When seismic ground shaking occurs, the soil is subjected to cyclic shear stresses that can cause excess hydrostatic pressures to develop. If excess hydrostatic pressures exceed the effective confining stress from the overlying soil, the soil may undergo deformation. If the soil undergoes virtually unlimited deformation without developing significant resistance, it is said to have liquefied. If the soil consolidates or vents to the surface during and following liquefaction, ground settlement and surface deformation may occur. Liquefaction-related ground settlement can result in differential movement and damage to structures.

Past occurrences of liquefaction from the 1906 San Francisco and 1989 Loma Prieta earthquakes are mapped near the project alignment. Most of these historic liquefaction sites were in areas of artificial fill over Bay Mud deposits (USGS 1978). USGS and CGS used these historic liquefaction sites and local geology to map liquefaction susceptibility in the San Francisco Bay Region (USGS 2005; USGS and CGS 2006). This mapping includes the entire RSA and shows areas with liquefaction susceptibility ranging from very low to very high. The mapped liquefaction susceptibility for the alignment alternatives is illustrated on Figure 3.9-11, while the locations with high to very high liquefaction susceptibility are shown in Table 3.9-6. Additional details regarding liquefaction are discussed in the Geology, Soils, and Seismicity Technical Reports, Section 5.4.1, Liquefaction (Authority 2019a, 2019b).

Table 3.9-6 Summary of High to Very High Liquefaction Susceptibility

Subsection	Percent of Alignment[1,2] Mapped as High to Very High Liquefaction Susceptibility	Description of Locations with High to Very High Liquefaction Susceptibility
San Francisco to South San Francisco	54%	Areas mapped as artificial fill and bay margin areas, including Islais Creek, Brisbane, Sierra Point, and San Bruno Canal.
San Bruno to San Mateo	9%	Limited areas, which include those mapped as artificial fill and creek channels just south of the existing Millbrae Station. The San Mateo Creek channel in northern San Mateo is also an area of high susceptibility.
San Mateo to Palo Alto	4%	Limited areas consisting mostly of creek channels including Laurel Creek, Cordilleras Creek, San Francisquito Creek, Matadero Creek, and Adobe Creek. Other areas with high susceptibility are near SR 92 and in central Redwood City.
Mountain View to Santa Clara	1%	Limited areas consisting mostly of creek channels including Stevens Creek in Mountain View and Saratoga Creek in Santa Clara.
San Jose Diridon Station Approach	2%	Limited areas consisting mostly of the Guadalupe River and Los Gatos Creek channels in San Jose.

Sources: Authority 2019a, 2019b
SR = State Route
[1] All percentages are based on approximate measurements of the alignment centerline.
[2] Based on Figure 3.9-11 (USGS and CGS 2006; USGS 2005)



Sources: USGS and CGS 2006; USGS 2005

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Figure 3.9-11 Liquefaction Susceptibility

Lateral Spreading

Lateral spreading can occur when sloping ground is underlain by liquefiable soil. When an earthquake causes strong ground shaking, the areas of sloping ground can translate laterally because of the loss of soil strength from liquefaction. For this movement to occur, the area must be near a free face (steep unconfined slope face) or slope such as a road cut or stream bank. Therefore, the risk of lateral spreading is affected by the likelihood of liquefaction, the ground slope, and the existence of free faces on the downhill side of the area in question. Lateral spreading can cause ground rupture or movement that may result in differential ground settlement and damage to structures.

Lateral spreading is possible in liquefaction-susceptible deposits near free faces or slopes created by bay margins or stream channels in limited locations within all subsections. Table 3.9-7 summarizes the areas susceptible to lateral spreading within each subsection. Additional details regarding lateral spreading are discussed in the Geology, Soils, and Seismicity Technical Reports, Section 5.4.2, Lateral Spreading (Authority 2019a, 2019b).

Table 3.9-7 Summary of Susceptibility to Lateral Spreading

Subsection	Percent of Alignment[1] Susceptible to Lateral Spreading	Description of Locations Susceptible to Lateral Spreading[2]
San Francisco to South San Francisco	12%	Mission Bay Channel, Islais Creek, Brisbane Lagoon, Oyster Point, and Colma Creek.
San Bruno to San Mateo	1%	Limited to localized stream channels including Mills Creek, Easton Creek, and San Mateo Creek.
San Mateo to Palo Alto	1%	Limited to localized stream channels including Laurel Creek, Cordilleras Creek, San Francisquito Creek, Matadero Creek, Adobe Creek, and Barron Creek.
Mountain View to Santa Clara	1%	Limited areas consisting mostly of creek channels including Permanente Creek, Stevens Creek, Saratoga Creek, Calabazas Creek, and San Tomas Aquinas Creek.
San Jose Diridon Station Approach	1%	Limited to localized stream channels including the Guadalupe River and Los Gatos Creek.

Sources: Authority 2019a, 2019b
[1] All percentages are based on approximate measurements of the alignment centerline.
[2] Susceptibility is based on areas considered to have high to very high liquefaction potential located near waterways.

Earthquake-Induced Landslides

Landslides and debris flows can be activated by ground shaking associated with earthquakes. Earthquake-induced landslides are most likely to occur in areas of steep slopes with poorly cemented or highly fractured rocks, areas underlain by weak soils, and areas on or adjacent to existing landslide deposits. The best available predictor of where movement of landslides might occur is the distribution of past movements (USGS 1975). Landslides can lead to ground deformation and debris flows that can cause damage to structures and be hazardous to people.

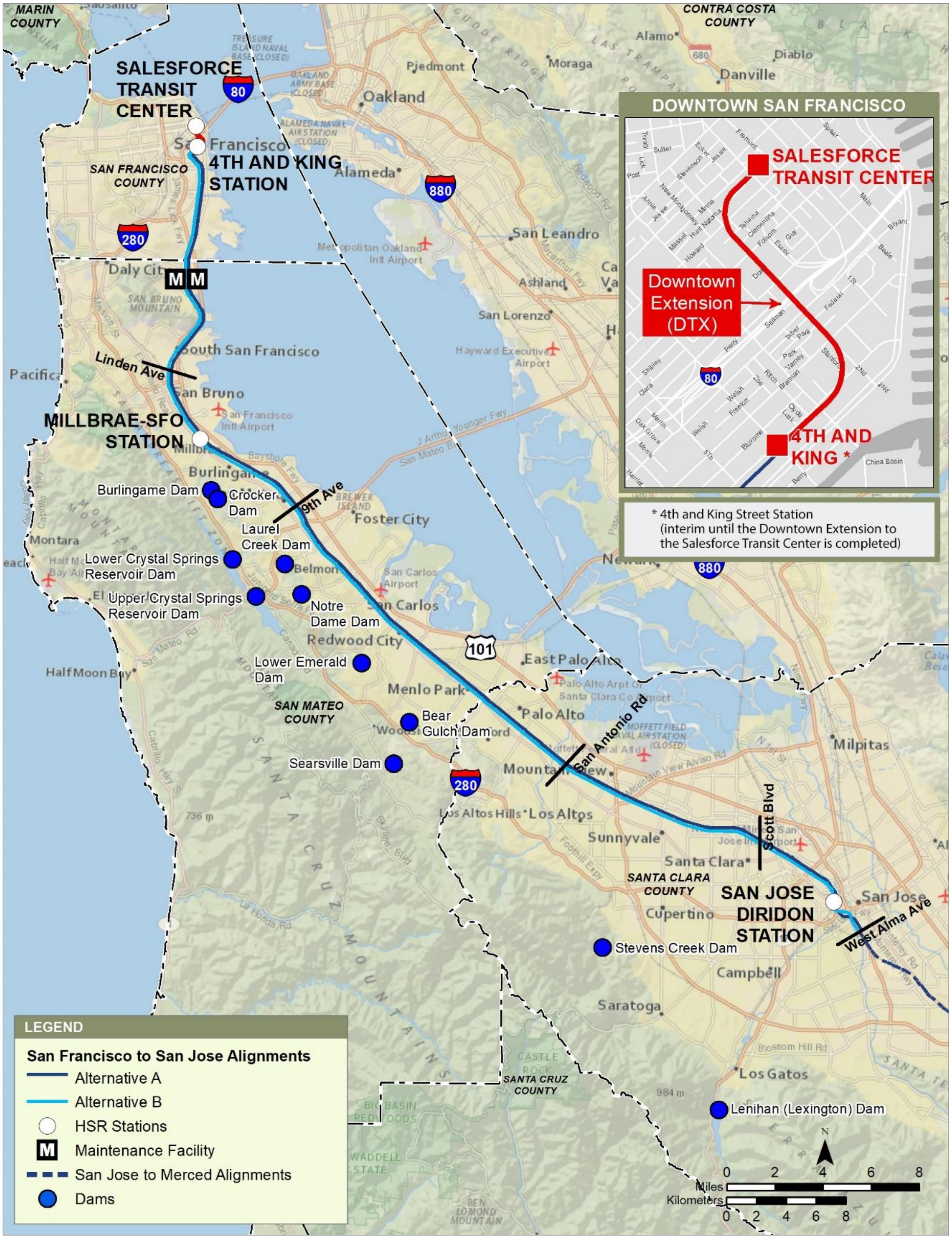
Most of the RSA is in low-lying valley areas with a low risk of seismically induced landslides. However, limited portions of the San Francisco to South San Francisco Subsection are in areas with mapped landslides where the alignment is near steep slopes. These areas include parts of Potrero Hill, Mount St. Joseph, Visitacion Valley, and near the San Bruno Mountain, and are shown on Figure 3.9-7.

Earthquake-Induced Flooding

Earthquake-induced flooding can occur in multiple ways: seiches, tsunamis, or the failure of water-retaining structures (such as dams) during an earthquake. Seiches occur when an enclosed body of water such as a bay, lake, river, or reservoir displaces significantly because of periodic oscillation caused by seismic waves. Seiches tend to occur because of intense seismic shaking or large earthquake-induced landslides rapidly displacing large volumes of water. A tsunami is an ocean wave that occurs when a large amount of water is displaced in a short period by seismic activity. Tsunamis typically are associated with submarine normal and reverse faults that displace a column of water vertically, generating large water waves that can travel across oceans. Earthquakes can also cause dam failure, which could result in flooding. All of these forms of earthquake-induced flooding can cause damage to structures and be hazardous to people.

The project alignment does not cross any mapped tsunami inundation zones (Cal EMA et al. 2009). Because of the confined nature of San Francisco Bay, a seiche is theoretically possible if an earthquake's shaking resonates with the natural frequency of the San Francisco Bay; however, there are no historical accounts of seiches in San Francisco Bay.

There are no reports of previous dam failures caused by ground shaking near the RSA; however, dam failure is theoretically possible given a strong enough earthquake. There are numerous dams in San Mateo County and Santa Clara County, as illustrated on Figure 3.9-12. San Mateo County has mapped dam failure inundation areas for 18 dams within the county. The project alignment crosses dam failure inundation areas for eight of these dams in the San Bruno to San Mateo and San Mateo to Palo Alto Subsections. The Mountain View to Santa Clara Subsection is in inundation areas from dam failure at two dams. The San Jose Diridon Station Approach Subsection is in inundation areas from dam failure at two dams. Figure 3.9-12 illustrates the locations of the dams that could cause earthquake-induced flooding in the RSA. Additional details regarding earthquake-induced flooding are discussed in the Geology, Soils, and Seismicity Technical Reports, Section 5.4.4, Earthquake-Induced Flooding (Authority 2019a, 2019b).



Source: USGS 2005

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Figure 3.9-12 Dams near Proposed Alignment

3.9.5.5 Geological Resources

Geological resources evaluated include mineral resources, fossil fuel (oil and gas) resources, and geothermal resources. As described in the subsequent sections, these geological resources have been dismissed from further consideration. Additional details regarding geologic resources are discussed in the Geology, Soils, and Seismicity Technical Reports, Section 5.5, Geological Resources (Authority 2019a, 2019b).

Mineral Resources

Mineral resources include minerals, aggregates, and building materials extracted from the earth by mining. The loss of availability of a locally important mineral resource recovery site is not anticipated because no active mineral resource recovery sites are mapped in the RSA. The project alignment does not pass through any additional active mining operations or production sites, and access to potential mineral resource reserves would not be precluded. As a result, this resource was dismissed from further consideration.

Fossil Fuel Resources (Oil and Natural Gas)

The California Department of Conservation DOGGR maintains a database of oil, gas, and geothermal resources, which indicates no active gas or oil wells are mapped within 0.5 mile of the project alignment (DOGGR n.d.). As a result, this resource was dismissed from further consideration.

Geothermal Resources

The California Department of Conservation DOGGR mapped no geothermal fields, wells, or known geothermal resource areas in the RSA (DOGGR n.d.). As a result, this resource was dismissed from further consideration.

3.9.5.6 Paleontological Resources

Geologic Conditions

According to published maps, the RSA is underlain by the Jurassic to Cretaceous–aged Franciscan Complex and Coast Range Ophiolite Complex, the Pleistocene to Pliocene–aged Merced Formation and Santa Clara Formation, the Pleistocene-aged Colma Formation, various unnamed Pleistocene-aged sedimentary deposits, various unnamed Holocene-aged sedimentary deposits, and Holocene to Pleistocene–aged fault rocks. Descriptions of geologic units not assigned to a named formation (e.g., Quaternary surface deposits) that are of similar age, deposition, and paleontological sensitivity have been grouped together for ease of reference. The geologic units in the RSA are the same for both project alternatives. Appendix A of the Paleontological Resources Technical Reports (Authority 2019c, 2019d) provide maps depicting the distribution of geologic units in the RSA and their paleontological potential.

Based on the literature review and museum records search results, the geologic units underlying the RSA have paleontological potential rankings that range from low potential to high potential in accordance with the SVP (2010) guidelines. The strata of the Merced, Santa Clara, and Colma Formations and (depending on lithology) older Quaternary alluvium deposits mapped in the RSA are considered to have a high paleontological potential because they are known to have produced numerous significant vertebrate fossils near the RSA and elsewhere. Certain areas of older Quaternary alluvium are considered to have an undetermined paleontological potential. Identifiable fossil remains discovered and salvaged from these geologic units during project construction would be scientifically important and significant.

The Franciscan Complex, Holocene-aged surficial alluvial deposits, and artificial fill have low paleontological potential for producing significant fossils. The Coast Range Ophiolite Complex has no paleontological potential. Table 3.9-8 summarizes the geologic units underlying the RSA and their assigned paleontological potential ratings. Refer to the Paleontological Resources Technical Reports (Authority 2019c, 2019d) for a more detailed discussion.

Table 3.9-8 Paleontological Potential of the Geologic Units Underlying the Resource Study Area

Map Symbol	Age and Legend ID	Geologic Unit	Location by Subsection	Lithology	Paleontological Sensitivity (SVP 2010[1])
Kjs, Kjsk, Kjc, Kjg, Kjm, Kju, KJc, KJss, fs, fcg fc, gb, sp, sph, fsr, fm	Upper Jurassic to Upper Cretaceous	Franciscan Complex	San Francisco to South San Francisco; San Bruno to San Mateo; San Jose Diridon Station Approach	Sandstone, chert, schist, greenstone, and other metamorphic rocks	Low
sc, sp	Jurassic and Cretaceous	Coast Range Ophiolite Complex	Outside alignment — proximal to San Jose Diridon Station Approach	Plutonic igneous, metamorphic	No
QTm	Pliocene	Merced Formation	San Bruno to San Mateo	Marine sand, silt, and clay with minor amounts of gravel and volcanic ash	High
Qsc	Pliocene	Santa Clara Formation	San Mateo to Palo Alto	Fluvial conglomerate, sandstone, and claystone; and lacustrine siltstone and claystone	High
Qc	Plio-Pleistocene	Colma Formation	San Francisco to South San Francisco; San Bruno to San Mateo	Marine and nonmarine mudstone, sandstone, conglomerate	High
Qu, Qsr, Qt, Qol, Qof, Qoa, Qm, QTs	Pleistocene	Older Quaternary Deposits	Throughout the RSA	Unconsolidated marine and nonmarine sand, silt, and clay	High to undetermined
Qd, Qyl, Ql, Qm, Qbm, Qac, Qb, Qal, Qam, Qya, Qaf, Qa2, Qa.2, Qa.1, Qa1, Qa, Qyfo, Qyf, Qsr	Holocene	Younger Quaternary Deposits	Throughout the RSA	Unconsolidated marine and nonmarine sand, silt, and clay	Low
Qaf, Qaf/tf, Qafs, Qf1, Qf2	Late Holocene	Artificial Fill	Throughout the RSA	Undefined and unconsolidated sediments derived from a variety of geologic formations	Low

Sources: USGS 1968, 1983, 1994, 1998a; Dibblee and Minch 2007a, 2007b
ID = identification
RSA = resource study area
SVP = Society of Vertebrate Paleontology
[1] For this project, SVP (2010) classification of high paleontological sensitivity corresponds to Caltrans High; undetermined paleontological sensitivity does not have an equivalent Caltrans ranking, low paleontological sensitivity corresponds to Caltrans Low, and no paleontological sensitivity corresponds to Caltrans No.

Paleontological Resources

University of California Museum of Paleontology (UCMP) staff conducted an institutional record search for previously recorded fossil localities within the RSA (UCMP 2016a, 2016b). The search results (Table 3.9-9) showed seven previously recorded vertebrate fossil localities in the RSA from unnamed Pleistocene deposits. These localities produced fossil remains of Ice Age land mammals, including *Camelops hesternus* (camel), *Bison latifrons* (giant bison), *Mammuthus* sp. (mammoth), *Mammuthus columbi* (mammoth), and Proboscidea (mammoth or mastodon) (UCMP 2016a, 2016b). In addition, the UCMP online database has fossil vertebrate localities from the Merced Formation, a fossil plant locality from the Santa Clara Formation, and fossil vertebrate, invertebrate, and plant localities from unnamed Pleistocene deposits in San Francisco County. The UCMP database has several fossil plant and invertebrate localities and one fossil vertebrate locality from the Merced Formation, and several fossil plant, invertebrate, and vertebrate localities in unnamed Pleistocene deposits in San Mateo County (UCMP 2016c). The UCMP database has several fossil vertebrate localities from the Santa Clara Formation and unnamed Pleistocene deposits in Santa Clara County (UCMP 2016d).

Table 3.9-9 Previously Recorded UCMP Fossil Vertebrate Localities Near (within 1 mile) of the Resource Study Area

Locality No.	Geologic Unit	Age	Resource Location	Relevant to Analysis of Subsections	Taxa
V3410	Unnamed Pleistocene Deposits	Pleistocene	San Francisco Embarcadero and James Lick Highway	San Francisco to South San Francisco	Mammals
V74164	Unnamed Pleistocene Deposits	Pleistocene	Community of North Fair Oaks Middlefield Road and Northside Avenue	San Mateo to Palo Alto	*Camelops hesternus*
V90003	Unnamed Pleistocene Deposits	Pleistocene	Menlo Park Sand Hill Road and El Camino Real	San Mateo to Palo Alto	*Bison latifrons*
V91248	Unnamed Pleistocene Deposits	Late Pleistocene	Mountain View Moffett Park Drive and North Mathilda Avenue	Mountain View to Santa Clara	Taxa list not published
V91128	Unnamed Pleistocene Deposits	Pleistocene	Santa Clara Lakeside Drive	Mountain View to Santa Clara	*Mammuthus* sp.
V99597	Unnamed Pleistocene Deposits	Pleistocene	Santa Clara	San Jose Diridon Station Approach	*Mammuthus columbi*
V99893	Unnamed Pleistocene Deposits	Pleistocene	Santa Clara	San Jose Diridon Station Approach	Proboscidea

Sources: UCMP 2016a, 2016b, 2016c, 2016d
sp. = species
UCMP = University of California Museum of Paleontology

A search of the Paleobiology Database (Paleobiology Database 2016) revealed an additional 12 fossil vertebrate and invertebrate localities in the Merced and Santa Clara Formations and surficial Quaternary nonmarine and marine deposits near the RSA. Localities within the Merced Formation occur in Santa Clara County and produced remains of marine bivalves and gastropods. One locality within the Santa Clara Formation occurs in Santa Clara County and produced remains of *Equus* sp. (horse). Localities within unnamed Pleistocene deposits in San Francisco County produced remains of *Odobenus rosmarus* (walrus) and *Hydrodamalis gigas* (sea cow). Localities from unnamed Pleistocene deposits within San Mateo County produced remains of *Mammuthus hayi* (mammoth), *Uria aalge* (bird), *Equus* sp. (horse), *Paramylodon harlani* (sloth), *Camelops* sp. (camel), *Bison* sp. (bison), and *Uria aalge* (bird), as well as invertebrate remains of barnacles, bivalves, and gastropods. A search of the California Academy of Sciences (CAS 2017) fossil collection database revealed an additional 27 fossil invertebrate and plant localities in San Francisco, San Mateo, and Santa Clara Counties in the Merced and Santa Clara formations. In addition, there are 21 fossil vertebrate localities recorded in the Colma Formation and unnamed Pleistocene deposits in San Francisco County. These consist of bones from *Mammuthus columbi* (mammoth) and *Bison latifrons* (bison). The Authority reviewed the PaleoPortal online database, which did not contain any previously recorded fossil vertebrate localities in the RSA or from the same geologic units elsewhere in San Francisco, San Mateo, or Santa Clara Counties (PaleoPortal Database 2016).

Paleontological Resource Sensitivity and Potential Evaluation by Geologic Unit

In total, construction activities associated with the project alternatives may affect three geologic units with high potential to produce significant paleontological resources and one geologic unit with high to undetermined potential (depending on lithology). Table 3.9-10 summarizes the geologic units potentially affected in each subsection. The geologic units in these subsections are the same for both project alternatives.

Table 3.9-10 Distribution of Geologic Units by Subsection in the Resource Study Area

	Subsection				
Resource	San Francisco to South San Francisco	San Bruno to San Mateo	San Mateo to Palo Alto	Mountain View to Santa Clara	San Jose Diridon Station Approach
Franciscan Complex (low potential)	X	X			X[1]
Coast Range Ophiolite Complex (no potential)					X[1]
Merced Formation (high potential)		X[2]			
Santa Clara Formation (high potential)			X[2]		
Colma Formation (high potential)	X	X			
Older Quaternary Deposits (high to undetermined potential)	X	X	X	X[2]	X[2]
Younger Quaternary Deposits (low potential)	X	X	X	X	X
Artificial Fill (low potential)	X	X	X	X	X[3]

Sources: USGS 1968, 1983, 1994, 1998a; Dibblee and Minch 2007a, 2007b
[1] No to low sensitivity unit not mapped at the surface within the alignment, but potentially present at depth.
[2] Sensitive geologic unit not mapped at the surface within the alignment but potentially present at depth.
[3] Artificial fill is mapped in the vicinity of the paleontological resources resource study area, and was observed in aerial photographs.

3.9.6 Environmental Consequences

3.9.6.1 Overview

This section discusses the potential exposure of the project alternatives to geology, soils, seismicity, and paleontological resources during construction and operations. Project features, including IAMFs, design standards, and compliance with the Authority's project design guidelines and technical memoranda, are incorporated into the project to address project construction and operation in areas with geologic, soil, and seismic hazards (collectively called geohazards). The Authority would require the design-build contractor to prepare and implement a construction management plan (CMP) to address geohazards during design and construction. Additionally, project features require adherence to applicable building codes, guidelines, and standards including those developed by American Association of State Highway and Transportation Officials (AASHTO), Federal Highway Administration (FHWA), American Railway Engineering and Maintenance-of-Way Association (AREMA), California Building Code, Caltrans, and American Society for Testing and Materials (GEO-IAMF#10). The Authority would also monitor for slope instability (GEO-IAMF#2) and subsidence (GEO-IAMF#9), install seismic early warning systems (GEO-IAMF#6), design for earthquake loads (GEO-IAMF#7), use motion sensors to shut down operations during or after an earthquake (GEO-IAMF#8), and implement track inspection systems (GEO-IAMF#9). These project actions would minimize exposure of people or structures to the effects of geohazards, including the risk of loss, injury, or death.

The project alternatives would also directly affect paleontological resources, including potentially destroying scientifically important fossil resources during ground disturbance in geologic units identified as having high or undetermined paleontological potential. The Authority would engage a qualified paleontological resources specialist (PRS) to review final design for the construction package and evaluate portions that would involve work in paleontologically sensitive units (either at the surface or in the subsurface) (GEO-IAMF#11, GEO-IAMF#12). It would also prepare and implement a paleontological resource monitoring and mitigation plan (PRMMP) that describes when and where construction monitoring would be required; emergency discovery procedures; sampling and data recovery procedures; procedures for the preparation, identification, analysis, and curation of fossil specimens and data recovered; and procedures for reporting (GEO-IAMF#13). The Authority would provide worker environmental awareness program (WEAP) training for project personnel (GEO-IAMF#14). The Authority would establish procedures to monitor and halt construction when paleontological resources are found (GEO-IAMF#15).

3.9.6.2 Geology, Soils, and Seismicity

Construction and operations of the project alternatives would result in temporary (short-term) or permanent (long-term) exposure to geologic, soil, and seismic hazards. This exposure could increase risk of property damage or injury from geologic, soil, and seismic hazards.

No Project Impacts

As discussed in Section 3.17, Regional Growth, the population in the Bay Area is expected to grow through 2040. Development in the region to accommodate the population and employment increase would continue under the No Project Alternative. The analysis of potential impacts of the No Project Alternative considers the effects of conditions forecasted by current land use and transportation plans in the vicinity of the project, including planned improvements to the highway, aviation, conventional passenger rail, freight rail, and port systems through the 2040 planning horizon. Without the HSR project, the forecasted population growth would increase pressure to expand highway and airport capacities. The Authority estimates that additional highway and airport projects (up to 4,300 highway lane miles, 115 airport gates, and 4 airport runways) would be needed to achieve equivalent capacity and relieve the increased pressure (Authority 2012). Section 3.18, Cumulative Impacts, identifies planned and other reasonably foreseeable future projects anticipated to be built in the region to accommodate the projected growth in the area, including shopping centers, industrial parks, transportation projects, and residential developments.

Under the No Project Alternative, recent development trends would be anticipated to continue. Construction and operation of infrastructure and development projects under the No Project Alternative would pose risks to public safety and create the potential for property damage caused by geologic and seismic hazards. The infrastructure and development projects would at a minimum be subject to the building code requirements of applying 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 and wind erosion, and loss of valuable topsoil. Future developments planned under the No Project Alternative would require individual environmental review, such as permits, regulatory requirements, and design standards. Future projects would need to comply with Title 24 California Building Code requirements for adherence to geotechnical and stability regulations and would be designed to avoid or minimize impacts.

Project Impacts

Construction Impacts

Construction of the project alternatives would consist predominantly of track modifications, relocation of overhead contact system (OCS) poles, and installation of communication radio towers, four-quadrant gates at at-grade crossings, and perimeter fencing along the right-of-way. At certain locations along the corridor, the project would relocate or close roadways, modify and expand existing stations, expand or build new structures, construct aerial structures (under Alternative B), and construct a new light maintenance facility (LMF) and additional passing track (under Alternative B). Activities associated with constructing this infrastructure include establishing limited equipment and materials storage areas close to construction sites; demolition of existing structures for Millbrae station expansion; clearing and grubbing; handling, storing, hauling, excavating, and placing fill; possible pile driving; and construction of bridges, road modifications, and utility relocations. Construction activities are described in Chapter 2, Alternatives.

Impact GEO#1: Construction on Unstable Soils

Unstable soil conditions would occur in areas subject to regional or localized ground subsidence, landslides, and soft soil conditions. The following subsections describe how the project would construct the specific project components on unstable soils.

Ground Subsidence

Regional ground subsidence is not an ongoing concern in the RSA because no significant regional groundwater extraction is occurring and no ongoing regional subsidence has been documented. Therefore, regional ground subsidence would be unlikely to affect the project.

Construction or modification of roadway and pedestrian underpasses, underground utilities, and bridges and culverts where groundwater levels may be locally higher because proximity to surface water could require temporary dewatering. Localized subsidence can occur when dewatering is necessary to facilitate excavations. Table 3.9-11 shows project elements where excavations below groundwater table may be necessary for construction.

Under both project alternatives, localized ground subsidence associated with temporary construction-related dewatering would be avoided through a pre-construction site assessment to determine the most appropriate design response (GEO-IAMF#10), application of design features to avoid exposure of people or structures (GEO-IAMF#1), and by monitoring and controlling the amount of groundwater withdrawal from the project. The project also would reinject groundwater at specific locations if necessary, or use alternate foundation designs to offset the potential for settlement. These project features would be incorporated into both project alternatives and would minimize acceleration of the rate or extent of ground subsidence under each project alternative. Therefore, construction activities would not increase exposure of people to loss of life or structures to destruction caused by ground subsidence. Despite Alternative B having more potential for dewatering because of passing track improvements including numerous undercrossings, there would be no substantial difference in construction impacts on ground subsidence between the two project alternatives.

Table 3.9-11 Potential for Construction below the Groundwater Table

Alternative A	Alternative B
San Francisco to South San Francisco Subsection	
Project elements for Alternative A that may extend below the groundwater table include: ▪ Foundations and below-grade structures (i.e., inspection pits) for the East Brisbane LMF ▪ Relocation of Bayshore Station and Tunnel Avenue overpass ▪ Bridge widening at the Guadalupe Valley Creek crossing ▪ Relocating control point Geneva ▪ Communication radio towers located approximately every 2.5 miles along the alignment requiring deep foundations (i.e., drilled piers); however, these foundations would likely be constructed without dewatering	Same as Alternative A, with the exception of the Brisbane LMF, which will be sited on the west side of the Caltrain corridor, and would require foundations and below-grade structure that may extend below the groundwater table
San Bruno to San Mateo Subsection	
Project elements for Alternative A that may extend below the groundwater table include: ▪ Widening of Hillcrest Boulevard underpass north of Millbrae Station ▪ Widening of Euclid Avenue pedestrian underpass ▪ Widening of Sanchez Creek and Mills Creek culverts ▪ Communication radio towers	Same as Alternative A
San Mateo to Palo Alto Subsection	
Project elements for Alternative A that may extend below the groundwater table consist of communication radio towers.	Same as Alternative A in the southern portion of the subsection. However, additional project elements that may extend below the groundwater table include: ▪ New pedestrian underpasses for the San Carlos Station relocation ▪ Underpass replacement or modification at Hillsdale Boulevard, 42nd Avenue, Belmont Station, Ralston Avenue, Harbor Boulevard, F Street, Holly Street and San Carolos Station, Arroyo Avenue, and Laurel Creek related to the new passing track ▪ Communication radio towers
Mountain View to Santa Clara Subsection	
Project elements for Alternative A that may extend below the groundwater table consist of communication radio towers.	Same as Alternative A

Alternative A	Alternative B
San Jose Diridon Station Approach Subsection	
Project elements for Alternative A that may extend below the groundwater table include: ▪ Reconstruction of College Park Caltrain Station ▪ Underpass replacement or modification at Bird Avenue and Delmas Avenue ▪ Foundations and below-grade structures for San Jose Diridon Station improvements ▪ Communication radio towers	Project elements for Alternative B that may extend below the groundwater table include: ▪ Deep foundations (i.e., drilled piers) for the viaduct support columns and straddle bents ▪ Foundations and below-grade structures for San Jose Diridon Station improvements ▪ New pedestrian underpass near the alignment at Emory Street (Viaduct to I-880 option) ▪ Replacement of overpasses at De La Cruz Boulevard and West Hedding Street with new underpasses (Viaduct to Scott Boulevard option) ▪ Replacement of pedestrian overpass at Lafayette Street with new underpass (Viaduct to Scott Boulevard option) ▪ Communication radio towers

Sources: Authority 2019a, 2019b
I- = Interstate
LMF = light maintenance facility

Landslides

Risks of landslides exist within the RSA in portions of the San Francisco to South San Francisco Subsection, particularly near steep slopes such as Potrero Hill, Mount St. Joseph, Visitacion Valley, and San Bruno Mountain. No construction activities would occur under either project alternative in these locations, except near San Bruno Mountain, because no modifications would be required to accommodate blended services. Only minor track shifts would occur north and south of San Bruno Mountain for both project alternatives; these track shifts would occur within the existing Caltrain rights-of-way and would have no effect on existing slopes that are susceptible to landslides.

Although the project is not anticipated to affect or be affected by landslides, there is a risk of landslides within the geologic hazards RSA and in particular in portions of the San Francisco to South San Francisco Subsection. As such, project features include measures to minimize the impacts of landslides. The design-build contractor would prepare and implement a CMP that would include design measures to minimize or avoid exposure of people or structures to impacts from landslides (GEO-IAMF#1). Prior to construction, site conditions would be assessed to determine the most appropriate engineering solutions to include in the CMP. The engineering solutions would comply with relevant design guidelines and standards (GEO-IAMF#10). The CMP would include design measures, such as structural solutions (e.g., tie backs, soil nails, retaining walls, debris barriers) or earthwork solutions (e.g., ground improvement, regrading/rebuilding of slopes), to stabilize or remove potentially unstable soils (GEO-IAMF#1). As a result of implementing these project features, construction activities would not increase exposure of people to injury or loss of life or property to damage or destruction from landslides. The potential for landslides to occur is the same for both Alternatives A and B, and the same project features would be incorporated into both alternatives; there would be no substantial difference in construction impacts between project alternatives.

Soft Soil

The project alternatives would include construction of facilities in areas that may be underlain by soft soil conditions. Construction elements in areas underlain by soft soil are shown in Table 3.9-12.

Table 3.9-12 Potential for Construction to be Affected by Soft Soil Conditions

Alternative A	Alternative B
San Francisco to South San Francisco Subsection	
Project elements for Alternative A that may be affected by soft soil conditions include: ▪ 4th and King Street Station modifications ▪ East Brisbane LMF and associated track and right-of-way modifications ▪ Relocation of Bayshore Station and Tunnel Avenue overpass ▪ Bridge widening at the Guadalupe Valley Creek crossing ▪ Relocating control point Geneva ▪ Communication radio towers	Same as Alternative A, with the exception of the Brisbane LMF, which would be sited on the west side of the Caltrain corridor.
San Bruno to San Mateo Subsection	
Project elements for Alternative A that may be affected by soft soil conditions include: ▪ San Bruno, Millbrae, Broadway Station and track modifications ▪ Communication radio towers ▪ Widening of Sanchez Creek and Mills Creek Culverts	Same as Alternative A
San Mateo to Palo Alto Subsection	
Project elements for Alternative A that may be affected by soft soil conditions include: ▪ Modifications to track, right-of-way, and retaining walls ▪ Communication radio towers	Same as Alternative A in the southern portion of the subsection. However, additional project elements that may be affected by soft soil conditions include: ▪ Passing track and associated track and station modifications at Hayward Park, Hillsdale, Belmont, San Carlos, and Atherton in the northern portion of the subsection, which would include new bridge structures and a retaining wall ▪ Communication radio towers
Mountain View to Santa Clara Subsection	
Project elements for Alternative A that may be affected by soft soil conditions include: ▪ Minor track and right-of-way modifications ▪ Communication radio towers	Same as Alternative A

Alternative A	Alternative B
San Jose Diridon Station Approach Subsection	
Project elements for Alternative A that may be affected by soft soil conditions include: ▪ Reconstruction of College Park Caltrain Station ▪ San Jose Diridon Station improvements ▪ New bridge structures at Taylor Street, I-280, Bird Avenue, Delmas Avenue, Prevost Street, SR 87, and Willow Street ▪ New bridge crossing the Guadalupe River ▪ Underpass replacement or modification at Bird Avenue and Delmas Avenue ▪ Communication radio towers	Project elements for Alternative B that may be affected by soft soil conditions include: ▪ Deep foundations (i.e., bored piles) for the viaduct support columns and straddle bents ▪ San Jose Diridon Station improvements ▪ New bridge structures at West Taylor Street and West Hedding Street (Viaduct to I-880 option) ▪ New pedestrian underpass near the alignment at Emory Street (Viaduct to I-880 option) ▪ Replacement of overpasses at De La Cruz Boulevard and West Hedding Street with new underpasses (Viaduct to Scott Boulevard option) ▪ Replacement of pedestrian overpass at Lafayette Street with new underpass (Viaduct to Scott Boulevard option) ▪ Communication radio towers

Sources: Authority 2019a, 2019b
I- = Interstate
LMF = light maintenance facility
SR = State Route

Construction of the Brisbane LMF under both project alternatives would occur on artificial fill that is likely underlain by Young Bay Mud. During construction, the design-build contractor would assess geotechnical conditions and, if necessary, employ ground improvement methods such as stone columns, cement deep-soil mixing, or jet grouting, or excavating and replacing soft soil with engineered fill. Heavily loaded structures, such as bridges and communication radio towers, would be constructed with deep foundations that would transfer the structural loads to noncompressible soil layers. Excavations through soft soil would be benched or braced to keep the excavation stable. Site conditions would be assessed prior to construction to determine the most appropriate engineering solutions, in accordance with relevant design guidelines and standards such as those developed by AREMA, FHWA, and Caltrans (GEO-IAMF#10). Additionally, prior to construction, the design-build contractor would prepare a CMP that would specify the details of how and where these techniques would minimize or avoid exposure of people or structures to impacts from soft soil (GEO-IAMF#1). As a result of implementing these project features, construction activities would not increase exposure of people to injury or loss of life or property to damage or destruction from differential settlement or ground failure caused by soft soil. The project features would be implemented on both project alternatives in areas underlain by soft soil, where necessary. Therefore, despite Alternative B having more potential for construction impacts from soft soil, because it includes a wider footprint in areas that may be underlain by soft soil to accommodate the passing track, there would be no substantial difference in construction impacts between alternatives.

CEQA Conclusion

The risks from building on unstable soils would be a less-than-significant impact under CEQA for both project alternatives because any localized ground subsidence associated with temporary construction-related dewatering would be avoided through a pre-construction site assessment to determine the most appropriate design response (GEO-IAMF#10, GEO-IAMF#1), and by monitoring and controlling the amount of groundwater withdrawal from the project. Any construction in areas prone to landslides would include structural solutions (e.g., tie backs, soil nails, retaining walls, debris barriers) or earthwork solutions (e.g., ground improvement, regrading/rebuilding of slopes), to stabilize or remove potentially unstable soils (GEO-IAMF#1). Excavations through soft soil would be benched or braced to keep the excavation stable in accordance with relevant design guidelines and standards such as those developed by AREMA, FHWA, and Caltrans (GEO-IAMF#10). Through the application of these features the project would not directly or indirectly increase exposure of people to injury or loss of life or property to damage or destruction from ground subsidence, landslides, and soft soil, beyond the level people currently experience in the RSA. Therefore, CEQA does not require any mitigation.

Impact GEO#2: Construction on Expansive Soils

Construction of both project alternatives in all subsections would occur predominantly in areas with expansive soils. The project elements that are most susceptible to the effects of expansive soil are those that involve new structures in areas with expansive soil. Table 3.9-13 shows project elements that would involve new structures in areas with expansive soil.

Table 3.9-13 Potential for Construction of New Structures in Areas with Expansive Soils

Alternative A	Alternative B
San Francisco to South San Francisco Subsection	
Project elements for Alternative A that may be affected by expansive soils include: ▪ 4th and King Street Station modifications ▪ East Brisbane LMF and associated track and right-of-way modifications ▪ Relocation of Bayshore Station and Tunnel Avenue overpass ▪ Bridge widening at the Guadalupe Valley Creek crossing ▪ Relocating control point Geneva ▪ Communication radio towers	Same as Alternative A, with the exception of the Brisbane LMF, which would be sited on the west side of the Caltrain corridor
San Bruno to San Mateo Subsection	
Project elements for Alternative A that may be affected by expansive soils include: ▪ San Bruno, Millbrae, and Broadway Station and track modifications ▪ Communication radio towers ▪ Widening of Hillcrest Boulevard underpass ▪ Widening of Euclid Avenue pedestrian underpass ▪ Widening of Sanchez Creek and Mills Creek culverts	Same as Alternative A
San Mateo to Palo Alto Subsection	
Project elements for Alternative A that may be affected by expansive soils include: ▪ Track, right-of-way, and retaining wall modifications ▪ Communication radio towers	Same as Alternative A in the southern portion of the subsection; however, additional project elements that may be affected by expansive soils include: ▪ Passing track and associated track and station modifications at Hayward Park, Hillsdale, Belmont, San Carlos, and Atherton in the northern portion of the subsection, which would include new bridge structures and a retaining wall ▪ Communication radio towers

Alternative A	Alternative B
Mountain View to Santa Clara Subsection	
Project elements for Alternative A that may be affected by expansive soils include: ▪ Minor track and right-of-way modifications ▪ Communication radio towers	Same as Alternative A
San Jose Diridon Station Approach Subsection	
Project elements for Alternative A that may be affected by expansive soils include: ▪ Reconstruction of College Park Caltrain Station ▪ San Jose Diridon Station improvements ▪ New bridge structures at Taylor Street, I-280, Bird Avenue, Delmas Avenue, Prevost Street, SR 87, and Willow Street ▪ New bridge crossing the Guadalupe River ▪ Underpass replacement or modification at Bird Avenue and Delmas Avenue ▪ Communication radio towers	Project elements for Alternative B that may be affected by expansive soils include: ▪ San Jose Diridon Station improvements ▪ New bridge structures at West Taylor Street and West Hedding Street (Viaduct to I-880 option) ▪ New pedestrian underpass near the alignment at Emory Street (Viaduct to I-880 option) ▪ Replacement of overpasses at De La Cruz Boulevard and West Hedding Street with new underpasses (Viaduct to Scott Boulevard option) ▪ Replacement of pedestrian overpass at Lafayette Street with new underpass (Viaduct to Scott Boulevard option) ▪ Communication radio towers

Sources: Authority 2019a, 2019b
I- = Interstate
LMF = light maintenance facility
SR = State Route

Project features would minimize or avoid the potential for expansive soil to cause differential movement of the track system by treating expansive soils with additives, such as cement or lime, to reduce the shrink-swell potential or excavating and replacing expansive soil with nonexpansive soil. Viaduct built on deep foundations would not be affected by expansive soils. Prior to construction, the design-build contractor would prepare a CMP that would specify the details of how and where these techniques would be implemented to minimize or avoid exposure of people or structures to impacts from expansive soil (GEO-IAMF#1). These project features would be implemented in accordance with relevant guidelines and standards such as those developed by AREMA, FHWA, and Caltrans (GEO-IAMF#10). As a result of implementing these project features, construction activities would not increase risks of injury or loss of life or exposure of property to damage or destruction from expansive soil. The project features that include the treatment or removal of expansive soil would be implemented on both project alternatives. Therefore, despite Alternative B having more potential for construction impacts from expansive soil because it includes more improvements in areas with expansive soil to accommodate the passing track, there would be no substantial difference in construction impacts between project alternatives.

CEQA Conclusion

The risks from constructing on expansive soils would be a less-than-significant impact under CEQA for both project alternatives because prior to construction, the design-build contractor would assess soil conditions and then treat expansive soils through engineering measures. Engineering measures would include treatment with soil additives to reduce shrink-swell potential or excavation and replacement in accordance with relevant guidelines and standards such as those developed by AREMA, FHWA, and Caltrans (GEO-IAMF#1, GEO-IAMF#10). Through the application of these project features the project would not directly or indirectly increase exposure of people to injury or loss of life or property to damage or destruction from expansive soil. Therefore, CEQA does not require any mitigation.

Impact GEO#3: Exposure of Concrete and Steel to Corrosive Soils

Project construction would occur in areas with moderate to highly corrosive soil and rock in each subsection. Impacts associated with corrosive soil are limited to construction that involves the use of concrete or steel in contact with potentially corrosive soil, such as building foundations, retaining walls, pavements, and underground utilities. Table 3.9-14 shows project elements that may involve the use of concrete or steel in contact with potentially corrosive soil.

Table 3.9-14 Construction of Project Elements Involving Concrete or Steel in Contact with Potentially Corrosive Soils

Alternative A	Alternative B
San Francisco to South San Francisco Subsection	
Project elements for Alternative A that would place concrete or steel infrastructure in contact with potentially corrosive soils include: ▪ 4th and King Street Station improvements ▪ East Brisbane LMF and associated track and right-of-way modifications ▪ Relocation of Bayshore Station and Tunnel Avenue overpass ▪ Bridge widening at the Guadalupe Valley Creek crossing ▪ Relocating control point Geneva ▪ Communication radio towers	Same as Alternative A, with the exception of the Brisbane LMF, which would be sited on the west side of the Caltrain corridor.
San Bruno to San Mateo Subsection	
None, as no potentially corrosive soils are mapped within this subsection	Same as Alternative A
San Mateo to Palo Alto Subsection	
Project elements for Alternative A that would place concrete or steel infrastructure in contact with potentially corrosive soils include: ▪ Track, right-of-way, and retaining wall modifications ▪ Communication radio towers	Same as Alternative A in the southern portion of the subsection; however, additional project elements that would place concrete or steel infrastructure in contact with potentially corrosive soils include: ▪ Passing track and associated track and station modifications at Hayward Park, Hillsdale, Belmont, San Carlos, and Atherton in the northern portion of the subsection, which would include new bridge structures and a retaining wall ▪ Communication radio towers
Mountain View to Santa Clara Subsection	
Project elements for Alternative A that would place concrete or steel infrastructure in contact with potentially corrosive soils include: ▪ Minor track and right-of-way modifications ▪ Communication radio towers	Same as Alternative A

Alternative A	Alternative B
San Jose Diridon Station Approach Subsection	
Project elements for Alternative A that would place concrete or steel infrastructure in contact with potentially corrosive soils include: ▪ Reconstruction of College Park Caltrain Station ▪ San Jose Diridon Station improvements ▪ New bridge structures at Taylor Street, I-280, Bird Avenue, Delmas Avenue, Prevost Street, SR 87, and Willow Street ▪ New bridge crossing the Guadalupe River ▪ Underpass replacement or modification at Bird Avenue and Delmas Avenue ▪ Communication radio towers	Project elements for Alternative B that would place concrete or steel infrastructure in contact with potentially corrosive soils: ▪ Deep foundations (i.e., bored piles) for the viaduct support columns and straddle bents ▪ San Jose Diridon Station improvements ▪ New bridge structures at West Taylor Street and West Hedding Street (Viaduct to I-880 option) ▪ New pedestrian underpass near the alignment at Emory Street (Viaduct to I-880 option) ▪ Replacement of overpasses at De La Cruz Boulevard and West Hedding Street with new underpasses (Viaduct to Scott Boulevard option) ▪ Replacement of pedestrian overpass at Lafayette Street with new underpass (Viaduct to Scott Boulevard option) ▪ Communication radio towers

Sources: Authority 2019a, 2019b
I- = Interstate
LMF = light maintenance facility
SR = State Route

Premature weathering of concrete and steel structures, resulting in a risk of failure of concrete and steel structures, would not occur from construction of the project alternatives because of the incorporation of engineering and construction methods to avoid or minimize the impacts of corrosive soil during construction (GEO-IAMF#1). The design-build contractor would prepare and implement a CMP identifying these methods, such as removing the corrosive soil, designing for corrosive conditions, and using corrosion-protected materials during construction. These methods would conform to guidelines specified by relevant transportation and building agencies and codes (GEO-IAMF#10). As a result of implementing these project features, construction of the project alternatives on corrosive soils would not result in an increased risk of injury or loss of life or exposure of structures to damage or destruction caused by premature weathering. The project features would be implemented on both project alternatives. Therefore, despite Alternative B having more potential for construction impacts from corrosive soil because it includes more improvements in areas with potentially corrosive soil to accommodate the passing track, there would be no substantial difference in construction impacts between project alternatives.

CEQA Conclusion

The risks from exposure to corrosive soils would be a less-than-significant impact under CEQA for both project alternatives because the design-build contractor would remove the corrosive soil, design for corrosive conditions, and use corrosion-protected materials (GEO-IAMF#1). These actions would be implemented in accordance with relevant guidelines and standards such as those developed by AREMA, FHWA, and Caltrans (GEO-IAMF#10). Through the application of these project features the project would not directly or indirectly increase exposure of people to injury or loss of life or property to damage or destruction from corrosive soil. Since the impact is less than significant, CEQA does not require any mitigation.

Impact GEO#4: Excavation and Grading Impacts on Soil Erosion

Impacts from soil erosion would be limited to ground-disturbing activities such as foundation or retaining wall construction and new structures (including pavement) that modify surface water runoff. Table 3.9-15 shows project elements that include ground-disturbing activities or new structures that could modify surface water runoff.

Table 3.9-15 Potential for Construction of Project Elements to Result in Soil Erosion

Alternative A	Alternative B
San Francisco to South San Francisco Subsection	
Project elements for Alternative A that have the potential to result in soil erosion include: ▪ 4th and King Street Station improvements ▪ East Brisbane LMF and associated track and right-of-way modifications ▪ Relocation of Bayshore Station and Tunnel Avenue overpass ▪ Bridge widening at the Guadalupe Valley Creek crossing ▪ Relocating control point Geneva ▪ Communication radio towers	Same as Alternative A, with the exception of the Brisbane LMF, which would be sited on the west side of the Caltrain corridor
San Bruno to San Mateo Subsection	
Project elements for Alternative A that have the potential to result in soil erosion include: ▪ San Bruno, Millbrae, and Broadway Station modifications, including the widening of Sanchez Creek and Mills Creek culverts ▪ Communication radio towers	Same as Alternative A
San Mateo to Palo Alto Subsection	
Communication radio towers	Same as Alternative A in the southern portion of the subsection; however, additional project elements that have the potential to result in soil erosion include the passing track and associated track and station modifications at Hayward Park, Hillsdale, Belmont, San Carlos, and Atherton in the northern portion of the subsection, which would include new bridge structures and a retaining wall
Mountain View to Santa Clara Subsection	
Communication radio towers	Same as Alternative A
San Jose Diridon Station Approach Subsection	
Project elements for Alternative A that have the potential to result in soil erosion: ▪ Reconstruction of College Park Caltrain Station ▪ San Jose Diridon Station improvements ▪ New bridge structures at Taylor Street, I-280, Bird Avenue, Delmas Avenue, Prevost Street, SR 87, and Willow Street ▪ New bridge crossing the Guadalupe River ▪ Underpass replacement or modification at Bird Avenue and Delmas Avenue	Project elements for Alternative B that have the potential to result in soil erosion: ▪ Deep foundations (i.e., bored piles) for the viaduct support columns and straddle bents ▪ San Jose Diridon Station improvements ▪ New bridge structures at West Taylor Street and West Hedding Street (Viaduct to I-880 option) ▪ New pedestrian underpass near the alignment at Emory Street (Viaduct to I-880 option) ▪ Replacement of overpasses at De La Cruz Boulevard and West Hedding Street with new underpasses (Viaduct to Scott Boulevard option) ▪ Replacement of pedestrian overpass at Lafayette Street with new underpass (Viaduct to Scott Boulevard option)

Sources: Authority 2019a, 2019b
I- = Interstate
LMF = light maintenance facility

SR = State Route

Communication radio towers, curve straightening, and other construction activities within the existing Caltrain right-of-way would have minimal soil erosion effects because they would not cause significant ground disturbance or increased runoff. Because the project alternatives share the same footprint along most of the alignment, the area of soil disturbance from the alternatives would be similar. Alternative A would result in 981 acres of disturbed soil, Alternative B (Viaduct to I-880) would result in 1,097 acres of disturbed soil, and Alternative B (Viaduct to Scott Boulevard) would result in 1,127 acres of disturbed soil (Authority 2019e). The estimated amount of soil disturbance in Alternative B (both viaduct options) is larger primarily because of a wider footprint along the proposed passing track, larger temporary disturbance areas associated with viaduct construction, and the soil disturbances associated with these footprints. Construction-related soil disruption would occur predominantly within the existing rail corridor and in the project footprint of the Brisbane LMF and would have no effect on farmland because no active farming occurs in the Project Section.

The project would minimize soil erosion from construction, including the loss of topsoil, through the implementation of BMPs that would protect exposed soil. The BMPs would be documented in a CMP and a construction stormwater pollution prevention plan (SWPPP) (GEO-IAMF#1, HYD-IAMF#3). Project design includes additional erosion control methods documented in the Caltrans Construction Manuals and the construction technical memorandum (GEO-IAMF#10). These erosion and sediment control methods would include stabilizing soil through the use of stabilizers, mulches, revegetation, and covering exposed work areas with biodegradable geotextiles (GEO-IAMF#1); watering for dust control; installing perimeter silt fences and sediment basins; and other site-specific BMPs. Project design also requires the preparation of a technical memorandum describing appropriate design guidelines and standards to be incorporated into facility design and construction (GEO-IAMF#10). Implementing these project features would require construction contractors to take soil properties into account during construction and would reduce soil erosion by implementing erosion control and sediment containment measures. The project features would be implemented on both project alternatives; therefore, despite Alternative B resulting in more acres of disturbed soil, there would be no substantial difference in construction impacts between project alternatives.

CEQA Conclusion

The risks from soil erosion and loss of topsoil would be less than significant under CEQA for both project alternatives because the project would implement erosion control and sediment containment measures, including the use of stabilizers, mulches, revegetation, and covering exposed work areas with biodegradable geotextiles; watering for dust control; building perimeter silt fences and sediment basins; and other site-specific BMPs (GEO-IAMF#1, GEO-IAMF#10, HYD-IAMF#3) to avoid affecting the viability of the ecosystem. There would be no effect on the productivity of farming in the area because no active farming occurs in the Project Section. Application of these project features would minimize, substantial soil erosion or the loss of topsoil. Therefore, CEQA does not require any mitigation.

Impact GEO#5: Difficult Excavations due to Shallow Bedrock and Shallow Groundwater

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 areas with shallow bedrock or shallow groundwater.

Shallow Bedrock

Shallow bedrock conditions can make construction excavations more difficult depending on the properties of the rock encountered, requiring potentially dangerous excavation methods. Most of the RSA is in areas of alluvium with no shallow bedrock. The risk of encountering shallow bedrock is expected to be limited to relatively small topographically elevated areas such as Potrero Hill, San Bruno Mountain, and the area near Belmont, which are mapped as Cretaceous and Jurassic bedrock as illustrated on Figures 3.9-1 through 3.9-5 (USGS 2006a).

Construction of the project alternatives would require excavations related to roadway modifications, station modifications, modifications to or construction of new structures, and construction of the new Brisbane LMF and additional passing track. No excavation would be anticipated in the upland areas of Potrero Hill, San Bruno Mountain, or near Belmont. Even though encounters with shallow bedrock would not be anticipated during construction, potential unforeseen effects of excavating shallow bedrock during construction would be addressed with conventional construction safety measures. The design-build contractor would prepare and implement a CMP that would include design measures to minimize or avoid exposure of people or structures to effects from shallow bedrock (GEO-IAMF#1). The contractor would develop safety procedures and guidelines for the use of potentially dangerous excavation methods and equipment. Conforming to guidelines specified by relevant transportation and building agencies and codes would require Authority contractors to account for geotechnical constraints during design and construction and thus minimize or avoid risks associated with shallow bedrock (GEO-IAMF#10). Geotechnical investigations would help to identify the areas where potentially difficult-to-excavate rock would be encountered so the contractor would use safe equipment and methods. Implementing these project features requiring construction safety measures would reduce the potential for shallow bedrock to cause loss of life or property damage during construction. The project features would be implemented on both project alternatives; therefore, despite Alternative B having more potential for construction impacts from shallow bedrock because it includes more undercrossings to accommodate the passing track, there would be no substantial difference in construction impacts between project alternatives.

Shallow Groundwater

Shallow groundwater could result in difficult excavation conditions if sufficient consideration is not given to specific conditions when excavating. Shallow groundwater can reduce the strength of the soil and cause instabilities of the excavation side-slopes or heave of the excavation base, leading to loss of ground support or total collapse. Exposure to shallow groundwater conditions would occur in limited locations where excavations extend below the groundwater. Excavations below the groundwater table may be necessary for construction of the same project elements described for Impact GEO#1 and shown in Table 3.9-11.

As described under Impact GEO#1, Construction on Unstable Soils, temporary construction dewatering could lead to localized ground subsidence. If a dewatering system fails during construction, excavations could flood and damage equipment or cause harm to people. The depth of groundwater varies with time because of changes in geology, weather, and human activities. Therefore, the impacts of shallow groundwater during construction could be intermittent.

Project features would minimize the impacts from excavating in areas with shallow groundwater by implementing commonly used construction methods. The design-build contractor would prepare and implement a CMP that would include design measures to minimize or avoid exposure of people or structures to impacts from shallow groundwater (GEO-IAMF#1). Conforming to guidelines specified by relevant transportation agencies and codes would require Authority contractors to account for geotechnical properties during design and construction to minimize hazardous impacts of shallow groundwater (GEO-IAMF#10). The contractors may use temporary dewatering with deep groundwater wells and well points that lower the water level, sheet pile wall systems to stabilize the soil, or jet grouting and cement deep-soil mixing techniques that add cement to the soil, thereby providing a cement-soil mix that resists hydrostatic forces. As a result of implementing these features, construction activities would not increase risks of injury or loss of life or exposure of property to damage or destruction beyond current exposure to shallow groundwater. The project features would be implemented on both project alternatives; therefore, despite Alternative B having more potential for construction impacts from shallow groundwater because it includes more undercrossings to accommodate the passing track, there would be no substantial difference in construction impacts between project alternatives.

CEQA Conclusion

The impact under CEQA would be less than significant for both project alternatives because the contractor would develop and implement a CMP that would include construction methods for conducting safe excavations in areas with shallow bedrock or shallow groundwater, such as worker safety training and shoring (GEO-IAMF#1). These project features would be implemented in accordance with relevant guidelines and standards (GEO-IAMF#10). Through the application of these project features the project would not render a currently stable geologic unit or soil unstable to a degree that it would directly or indirectly increase exposure of people to injury or loss of life or property to damage or destruction, associated with excavating in areas with shallow bedrock or shallow groundwater. Therefore, CEQA does not require any mitigation.

Impact GEO#6: Construction on Landfills

Landfills pose hazards for construction associated with the release of flammable gases (e.g., methane) and the potential for ground settlement because of the compressibility of buried refuse and decomposition of organic materials. Construction of the East Brisbane LMF under Alternative A would require significant earthwork cut and fill to create a level surface for the workshop, yard, tracks, and supporting systems and utilities on the site of the former Brisbane Landfill. Prior to construction of Alternative A, the contractor would prepare a CMP that would include gas monitoring during construction. The contractor would follow the Occupational Safety and Health Administration, U.S. Environmental Protection Agency, and Department of Toxic Substances Control regulatory requirements for construction on landfills, thereby reducing risks associated with landfill gas. In addition, the project would use safe and explosion-proof equipment as well as testing for gases regularly and installing gas monitoring and venting systems (GEO-IAMF#3). Structures founded on a landfill would be built using the latest California Building Code, requiring the contractor to account for ground settlement resulting from the compression or decomposition of landfill refuse (GEO-IAMF#10). Contractors could employ ground improvement such as preloading to reduce future ground settlement or using deep foundations systems such as piles to transfer the weight of a building to soil/rock below the refuse (GEO-IAMF#1). With the implementation of these project features, construction of Alternative A would make sure that there is no route of exposure to landfill gas that results in a substantial risk of loss of life or destruction of property, nor would construction of Alternative A result in increased risk of injury or loss of life or destruction of property from ground settlement from compression or decomposition of landfill refuse. The project features would avoid or minimize risks associated with construction on a former landfill under Alternative A.

Construction of the West Brisbane LMF under Alternative B would require similar construction activities to create a level surface for the workshop, yard, tracks, and supporting systems and utilities; however, construction would occur approximately 450 feet west of the former Brisbane Landfill. Construction of Alternative B would not expose people or structures to risks associated with construction on landfills. Although Alternative B would not involve construction on the site of the former Brisbane Landfill, subsurface migration of methane or other landfill gases could pose a risk. Prior to construction of Alternative B, the contractor would prepare a CMP that would include gas monitoring during construction. The contractor would follow the Occupational Safety and Health Administration, U.S. Environmental Protection Agency, and Department of Toxic Substances Control regulatory requirements for construction in areas of potential vapor intrusion, thereby reducing risks associated with landfill gas (GEO-IAMF#3). With the implementation of these project features, construction of Alternative B would make sure there is no route of exposure to landfill gas that results in a substantial risk of loss of life or destruction of property.

There would be no substantial difference in impacts between the project alternatives because the project features would minimize risks associated with construction on a landfill under Alternative A. Despite Alternative B not being located on a landfill, potential risks associated with subsurface migration of landfill gases would be minimized through the implementation of project features.

CEQA Conclusion

The gases and ground settlement risks from constructing on a former landfill would be less than significant under CEQA for Alternatives A and B because project features would make sure that there is no route of exposure to landfill gas associated with the former Brisbane Landfill that results in substantial risks of loss of life or destruction of property, and also that there is no increased risk of loss of life or destruction of property from ground settlement from compression or decomposition of landfill refuse by using safe construction methods, monitoring for gases, and preloading structural areas (GEO-IAMF#1, GEO-IAMF#3, GEO-IAMF#10). Through the application of these project features the project would not directly or indirectly provide a route of exposure for landfill gas or increase exposure of people to injury or loss of life or property to damage or destruction from landfill gas. Therefore, CEQA does not require any mitigation.

Impact GEO#7: Primary Seismic Hazards during Construction

Seismic events, such as surface fault ruptures and seismically induced ground shaking, could affect construction and increase the risk of injury and loss of life to construction personnel and damage to HSR property. These phenomena can affect structural integrity by undermining the substrate on which structures are built or shaking the structures.

Surface Fault Rupture

The project footprint does not lie within a current Alquist-Priolo earthquake fault zone or cross any mapped Holocene active faults; however, it is near or crosses faults mapped as Quaternary age in the San Mateo to Palo Alto and Mountain View to Santa Clara Subsections. Prior to construction, project features would include a three-tiered analysis to characterize the potential for hazardous fault displacements (Authority 2014). First, an initial screening would be performed to identify potentially hazardous fault zones. Second, potentially hazardous fault zones would be further evaluated to determine if they meet the criteria for hazardous fault zones. Third, estimates of fault displacements at hazardous fault zones would be made for purposes of design. The design-build contractor would prepare and implement a CMP that would include design measures to minimize or avoid exposure of people or structures to effects from surface fault rupture, including worker safety protocols for seismic events that could occur during construction (GEO-IAMF#1). The design measures would conform to relevant guidelines specified by transportation and building agencies and codes (GEO-IAMF#10) requiring contractors to account for seismic hazards during design and construction. As a result of implementing these project features, construction activities would not increase risks of injury or loss of life or exposure of property to damage or destruction from surface fault ruptures beyond the current risk. Project features would be implemented on both project alternatives. As the potential risk of surface fault rupture is the same for both Alternatives A and B because the locations where the project is near or crosses faults is the same for both alternatives, there would be no substantial difference in construction impacts between project alternatives.

Ground Shaking

The entire project alignment is in a region with active and potentially active faults (seismic sources) that are considered capable of causing strong ground shaking. All project components would be designed to resist potential movements, shear forces, and displacements caused by seismic ground shaking. The contractor would conduct seismic studies to establish up-to-date seismic ground motions for design (GEO-IAMF#7). Prior to construction, the design-build contractor would prepare a CMP that would include design measures to minimize or avoid exposure of people or structures to effects from seismic ground shaking, including worker safety protocols for seismic events that could occur during construction (GEO-IAMF#1). The design measures would conform to relevant guidelines and standards (GEO-IAMF#10). Construction activities would not increase exposure of people to potential loss of life or injury or structures to damage or destruction because of seismic ground shaking beyond what they are currently exposed to. Ground shaking is a regional hazard and therefore the project features would be implemented on both project alternatives, and there would be no substantial difference in construction impacts between project alternatives.

CEQA Conclusion

The risks during construction from surface fault ruptures and seismically induced ground shaking would be less than significant under CEQA for both project alternatives because design and construction practices to minimize risk from primary seismic hazards include the implementation of a CMP (GEO-IAMF#1) and evaluation and design for seismic ground shaking (GEO-IAMF#7) in accordance with guidelines and standards specified by relevant transportation and building agencies (GEO-IAMF#10). Through the application of these project features, the project would not directly or indirectly increase exposure of people to injury or loss of life or property to damage or destruction from surface fault rupture and ground shaking during construction, beyond the level people currently experience in the RSA. Therefore, CEQA does not require any mitigation.

Impact GEO#8: Secondary Seismic Hazards during Construction

Risks associated with secondary seismic hazards (i.e., liquefaction, lateral spreading, earthquake-induced landslides, and earthquake-induced dam failure) could affect construction and increase the risk of injury and loss of life to construction personnel and damage to HSR property.

Liquefaction

The project alternatives would cross areas of potential liquefaction in each subsection. Construction impacts from liquefaction would be limited to project elements involving new structures in areas mapped as susceptible to liquefaction (Table 3.9-16).

Table 3.9-16 Potential for Construction of Project Elements to be Affected by Liquefaction

Alternative A	Alternative B
San Francisco to South San Francisco Subsection	
Project elements for Alternative A that have the potential to be affected by liquefaction include: ▪ 4th and King Street Station improvements ▪ East Brisbane LMF and associated track and right-of-way modifications ▪ Relocation of Bayshore Station and Tunnel Avenue overpass ▪ Bridge widening at the Guadalupe Valley Creek crossing ▪ Relocating control point Geneva ▪ Communication radio towers	Same as Alternative A, with the exception of the Brisbane LMF, which would be sited on the west side of the Caltrain corridor
San Bruno to San Mateo Subsection	
Project elements for Alternative A that have the potential to be affected by liquefaction include: ▪ San Bruno, Millbrae, and Broadway Station modifications ▪ Widening of Hillcrest Boulevard underpass ▪ Widening of Sanchez Creek and Mills Creek culverts ▪ Communication radio towers	Same as Alternative A
San Mateo to Palo Alto Subsection	
Project elements for Alternative A that have the potential to be affected by liquefaction: ▪ Track, right-of-way, and retaining wall modifications ▪ Communication radio towers	Same as Alternative A in the southern portion of the subsection; however, additional project elements that have the potential to be affected by liquefaction include: ▪ Passing track and associated track and station modifications at Hayward Park, Hillsdale, Belmont, San Carlos, and Atherton in the northern portion of the subsection, which would include new bridge structures and a retaining wall ▪ Communication radio towers
Mountain View to Santa Clara Subsection	

Alternative A	Alternative B
Project elements for Alternative A that have the potential to be affected by liquefaction: ▪ Minor track and right-of-way modifications ▪ Communication radio towers	Same as Alternative A
San Jose Diridon Station Approach Subsection	
Project elements for Alternative A that have the potential to be affected by liquefaction: ▪ New bridge crossing the Guadalupe River ▪ Communication radio towers	Project elements for Alternative B that have the potential to be affected by liquefaction: ▪ Deep foundations (i.e., bored piles) for the viaduct support columns and straddle bents (depending on their final locations) ▪ Communication radio towers

Sources: Authority 2019a, 2019b
LMF = light maintenance facility

During construction, the design-build contractor would assess geotechnical conditions and employ ground improvement methods, such as stone columns, deep dynamic compaction, cement deep-soil mixing, jet grouting, or excavating and replacing liquefiable soil with engineered fill. Prior to construction, the design-build contractor would prepare a CMP that would specify the details of how and where these techniques would minimize or avoid exposure of people or structures to impacts from liquefaction (GEO-IAMF#1). Geotechnical conditions would be assessed to determine the extent of the hazard and the most appropriate engineering solutions prior to construction, in accordance with relevant design guidelines and standards (GEO-IAMF#10). With implementation of these project features, construction activities would not increase risks of injury or loss of life or exposure of property to damage or destruction beyond what they are currently exposed to because of liquefaction. The project features would be implemented on both project alternatives; therefore, although Alternative B would have more construction in areas mapped as susceptible to liquefaction because of the passing track improvements, there would be no substantial difference in construction impacts between project alternatives.

Lateral Spreading

The project alternatives would cross areas of mapped liquefaction susceptibility adjacent to or near areas of sloping ground. Construction impacts from lateral spreading would be limited to the new project elements that would be built in the areas with potential for lateral spreading (Table 3.9-17).

The design-build contractor would assess geotechnical conditions to determine the extent of the hazard and the most appropriate engineering solutions prior to construction, in accordance with the California Building Code and relevant geotechnical guidelines and standards by AASHTO, FHWA, and Caltrans (GEO-IAMF#10). The project would minimize liquefaction and lateral spreading through the use of stone columns, deep dynamic compaction, cement deep-soil mixing, and jet grouting, or excavating and replacing liquefiable soil with engineered fill. Prior to construction, the design-build contractor would prepare a CMP that would specify the details of how and where these techniques would minimize the impacts on people and structures from lateral spreading (GEO-IAMF#1). Implementation of these project features would minimize risk of liquefaction and lateral spreading, and therefore construction of the project would not increase risks of injury or loss of life or exposure of property to damage or destruction because of liquefaction and lateral spreading beyond current exposure. The project features would be implemented on both project alternatives; therefore, despite Alternative B having more construction in areas with potential for lateral spreading because of the passing track improvements, there would be no substantial difference in construction impacts between project alternatives.

Table 3.9-17 Potential for Construction of Project Elements to be Affected by Lateral Spreading

Alternative A	Alternative B
San Francisco to South San Francisco Subsection	
Project elements for Alternative A that have the potential to be affected by lateral spreading include: ▪ East Brisbane LMF and associated track and right-of-way modifications ▪ Bridge widening at the Guadalupe Valley Creek crossing ▪ Tunnel Avenue overpass relocation ▪ Communication radio towers near Brisbane Lagoon	Same as Alternative A, with the exception of the Brisbane LMF, which would be sited on the west side of the Caltrain corridor
San Bruno to San Mateo Subsection	
Project elements for Alternative A that have the potential to be affected by lateral spreading include: ▪ Widening of Sanchez Creek and Mills Creek culverts ▪ Widening of Hillcrest Boulevard underpass	Same as Alternative A
San Mateo to Palo Alto Subsection	
Project elements for Alternative A that have the potential to be affected by lateral spreading include track modifications over Laurel Creek, Belmont Creek, Pulgas Creek, and Cordilleras Creek, as well as Borel Creek	Project elements for Alternative A that have the potential to be affected by lateral spreading include the passing track over Laurel Creek, Belmont Creek, Pulgas Creek, and Cordilleras Creek, as well as the new bridge structure over Borel Creek
Mountain View to Santa Clara Subsection	
Project elements for Alternative A that have the potential to be affected by lateral spreading include track modifications over Permanente Creek, Stevens Creek, Calabazas Creek, and Saratoga Creek	Same as Alternative A
San Jose Diridon Station Approach Subsection	
New bridge crossing the Guadalupe River	Same as Alternative A

Sources: Authority 2019a, 2019b
LMF = light maintenance facility

Earthquake-Induced Landslides

Risks of earthquake-induced landslides in the RSA exist in portions of the San Francisco to South San Francisco Subsection, particularly near steep slopes such as Potrero Hill, Mount St. Joseph, Visitacion Valley, and San Bruno Mountain. No construction activities would occur in proximity to Potrero Hill, Mount St. Joseph, or Visitacion Valley, including at the existing tunnel portals, under either project alternative. Minor track shifts would occur north and south of San Bruno Mountain for both project alternatives; these track shifts would occur within the existing Caltrain rights-of-way and would have no effect on existing slopes that are susceptible to landslides.

While construction activities would not occur in the portions of the San Francisco to South San Francisco Subsection that have been identified as being at risk of earthquake-induced landslides, there is a risk of landslides within the seismicity, faulting, and dam failure inundation RSA. However, implementation of project features would minimize impacts of earthquake-induced landslides. Project features would include conducting detailed landslide evaluations in landslide-prone areas to determine appropriate engineering solutions prior to construction, in accordance with relevant design guidelines and standards (GEO-IAMF#10). Slope stability would be assessed using the most recently updated Authority seismic design criteria (GEO-IAMF#7). Prior to construction, the design-build contractor would prepare a CMP that would include design measures such as structural solutions (e.g., tie backs, soil nails, retaining walls, debris barriers) or earthwork solutions (e.g., ground improvement, regrading/rebuilding of slopes) to minimize or avoid the impacts of earthquake-induced landslides (GEO-IAMF#1). Construction activities would not increase risks of injury or loss of life or exposure of property to damage or destruction beyond what they are currently exposed to because of earthquake-induced landslides**.** The potential for earthquake-induced landslides to occur is the same for both Alternatives A and B; therefore, following the implementation of the project features on both project alternatives, there would be no substantial difference in construction impacts between project alternatives.

Earthquake-Induced Flooding

There are no reports of previous dam failures caused by ground shaking or a seiche near the RSA; however, dam failure is theoretically possible given a strong enough earthquake. The project alignment crosses dam failure inundation areas in the San Bruno to San Mateo, San Mateo to Palo Alto, Mountain View to Santa Clara, and San Jose Diridon Station Approach Subsections. Earthquake-induced flooding would be addressed with construction safety measures. The design-build contractor would prepare and implement a CMP that would include features to reduce the potential for earthquake-induced flood hazards to increase risks of injury, loss of life, and property damage during construction (GEO-IAMF#1). This may include evacuation plans as well as earthquake response training for workers. Conforming to guidelines specified by relevant transportation and building agencies and codes would require contractors to account for drainage patterns and topography during design and construction and thus be able to establish safe evacuation areas for construction workers (GEO-IAMF#10). With implementation of these project features, construction activities would not increase risks of injury or loss of life or exposure of property to damage or destruction beyond current conditions because of earthquake-induced flooding. The location and footprint of both project alternatives are similar, especially in comparison to the scale of earthquake-induced flooding, and therefore following the implementation of the project features on both project alternatives, there would be no substantial difference in construction impacts between project alternatives.

CEQA Conclusion

The risks during construction from liquefaction, lateral spreading, earthquake-induced landslides, and earthquake-induced flooding would be less than significant under CEQA for both project alternatives because project features would include preparation and implementation of a CMP that would include construction methods designed for secondary seismic hazards (GEO-IAMF#1). The construction would also conform to guidelines specified by relevant transportation and building agencies (GEO-IAMF#10). Through the application of these project features, the project would not directly or indirectly increase exposure of people to injury or loss of life or property to damage or destruction from secondary seismic hazards during construction, beyond the level people currently experience in the RSA. Therefore, CEQA does not require any mitigation.

Operations Impacts

Operations of the project alternatives would involve scheduled train travel along the blended system through the Bay Area, as well as inspection and maintenance along the track and railroad right-of-way, at stations, and on structures, fencing, power system, positive train control, and communications. Chapter 2 more fully describes operational and maintenance activities.

Impact GEO#9: Primary Seismic Hazards during Operations

Seismic events, such as surface fault ruptures and seismically induced ground shaking, could affect operation and increase the risk of injury and loss of life to passengers and damage to HSR property. These phenomena can affect structural integrity by undermining the substrate on which structures are built or shaking the structures.

Surface Fault Rupture

The project alignment does not cross any known Holocene active faults, defined as displacement during the past 11,700 years (CGS 2010b). The alignment does cross the San Jose fault in the Mountain View to Santa Clara Subsection and is near the Stanford fault in the San Mateo to Palo Alto Subsection. The San Jose fault and the Stanford fault are mapped as Quaternary (age undifferentiated), defined as displacement within the last 1.6 million years (CGS 2010b). Potential operations impacts from surface fault rupture are anticipated to be limited to these fault locations.

Project features would include an assessment of faults considered hazardous and their resulting estimated displacements for the purposes of design (Authority 2014). Structural design would conform to relevant guidelines specified by transportation and building agencies and codes (GEO-IAMF#10) requiring the design to account for surface fault rupture. Caltrain currently uses, and the blended system would continue to use, the University of California at Berkeley's Rapid Earthquake Data Integration System to determine the magnitude and location of earthquakes and their possible impact on track and structures. Depending on magnitude and location, earthquakes may trigger a system response such as slowing or halting train operations until track inspection and any necessary repairs can be completed. For dedicated HSR facilities, the Authority would incorporate a ground rupture early warning system, motion sensing instruments, and a signal train control system to shut down operations during or after a potentially damaging earthquake (GEO-IAMF#6, GEO-IAMF#8). The train system would be inspected for damage and then returned to service or repaired, if necessary (GEO-IAMF#8). With implementation of these project features, operations would not increase exposure of people to loss of life or structures to destruction beyond the current risk of surface fault ruptures. Project features would be implemented on both project alternatives. The potential risk of surface fault rupture would be the same for both Alternatives A and B because the alternatives are the same at the locations where the project is near or crosses faults. There would be no substantial difference in operations impacts between project alternatives.

Seismic Ground Shaking

The design of project components to resist potential movements, shear forces, and displacements caused by seismic ground shaking (GEO-IAMF#7) would minimize effects of ground shaking during project operations. 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. The blended system would rely on the University of California at Berkeley's Rapid Earthquake Data Integration System for earthquake detection. The dedicated HSR facilities would incorporate an earthquake early warning system, motion sensing instruments, and a train control system to shut down project operations during or after a significant earthquake (GEO-IAMF#6, GEO-IAMF#8). The train system would be inspected for damage and then returned to service or repaired, if necessary (GEO-IAMF#8). Operations would not expose people to potential injury or loss of life or property to damage or destruction beyond current exposure to seismic ground shaking. Ground shaking is a regional hazard that would affect the entire Project Section, and therefore the project features would be implemented on both project alternatives and there would be no substantial difference in operations impacts between project alternatives.

CEQA Conclusion

The impact under CEQA would be less than significant because project design features would use seismic design standards in the structural design (GEO-IAMF#7), use early warning systems that would be triggered by strong ground motion (GEO-IAMF#6), and shut down train operations during or after an earthquake (GEO-IAMF#8) to minimize injury, loss of life, and structural damage from surface fault rupture and ground shaking during operations. Through the application of these project features, the project would not directly or indirectly increase exposure of people to injury or loss of life or property to damage or destruction due to primary seismic hazards during operations, beyond the level people currently experience in the RSA. Therefore, CEQA does not require any mitigation.

Impact GEO#10: Secondary Seismic Hazards during Operations

Risks associated with secondary seismic hazards (i.e., liquefaction, lateral spreading, earthquake-induced landslides, and earthquake-induced dam failure) could affect operation and increase the risk of injury and loss of life to passengers and damage to HSR property.

Liquefaction

Where the project would construct new permanent infrastructure, as described under Impact GEO#8, liquefiable soils would be characterized and, if necessary, improved or removed, avoiding the likelihood of differential movement of the tracks or structures during operations because of lateral spreading (GEO-IAMF#1). This would minimize ground deformation caused by lateral spreading in newly built areas. The Brisbane LMF and maintenance activities that involve the replacement or reconstruction of project elements would be designed and built in accordance with the California Building Code and relevant geotechnical guidelines and standards by AASHTO, FHWA, and Caltrans (GEO-IAMF#10). The blended system would rely on the University of California at Berkeley's Rapid Earthquake Data Integration System for earthquake detection, while new dedicated HSR facilities would incorporate motion-sensing instruments and a control system to shut down HSR operation during or after a potentially damaging earthquake so that damage could be assessed and, if necessary, repaired (GEO-IAMF#6, GEO-IAMF#8). With implementation of these project features, operations would not increase exposure of people to loss of life or structures to destruction beyond what they are currently exposed to from liquefaction. The project features would be implemented on both project alternatives such that despite Alternative B having more operable track in areas mapped as susceptible to liquefaction because of the passing track, there would be no substantial difference in operations impacts between project alternatives.

Lateral Spreading

Where the project would build new structures, as listed under Impact GEO#8, liquefiable soils would be characterized, and if necessary, improved or removed during construction, minimizing the likelihood of lateral spreading of these new project structures during operations (GEO-IAMF#1). The Brisbane LMF and maintenance activities that involve the replacement or reconstruction of project elements would be designed and constructed in accordance with the California Building Code and relevant geotechnical guidelines and standards by AASHTO, FHWA, and Caltrans (GEO-IAMF#10). The blended system would rely on the University of California at Berkeley's Rapid Earthquake Data Integration System for earthquake detection, while new dedicated HSR facilities would incorporate motion-sensing instruments and a control system to shut down HSR operation during or after a potentially damaging earthquake so that damage could be assessed and, if necessary, repaired (GEO-IAMF#6, GEO-IAMF#8). With implementation of these project features, operations would not increase exposure of people to loss of life or structures to destruction because of lateral spreading beyond current exposure. The project features would be implemented on both project alternatives such that despite Alternative B having more operable track in areas with potential for lateral spreading because of the passing track, there would be no substantial difference in operations impacts between project alternatives.

Earthquake-Induced Landslides

The potential effects of earthquake-induced landslides on project operations would be limited to portions of the San Francisco to South San Francisco Subsection, particularly near steep slopes such as Potrero Hill, Mount St. Joseph, Visitacion Valley, and San Bruno Mountain. Project features to stabilize or remove existing landslides during construction (GEO-IAMF#1) would also minimize potential risks from earthquake-induced landslides on project operations. In addition, the Authority would incorporate slope monitoring by a state-registered engineering geologist into the operation and maintenance procedures to promote the long-term stability of slopes near the project (GEO-IAMF#2). As a result of implementing these project features, operations would not increase exposure of people to injury or loss of life or of property to damage or destruction beyond current exposure to earthquake-induced landslides. The potential for earthquake-induced landslides to occur is the same for both Alternatives A and B. The project features would be implemented under both project alternatives, and, therefore, there would be no substantial difference in operations impacts between alternatives.

Earthquake-Induced Flooding

The potential effects of earthquake-induced flooding on project operations would be limited to areas susceptible to dam failure inundation in the San Bruno to San Mateo, San Mateo to Palo Alto, and San Jose Diridon Station Approach Subsections. The blended system would rely on the University of California at Berkeley's Rapid Earthquake Data Integration System for earthquake detection, while new dedicated HSR facilities would include an earthquake early warning system that detects ground motion and that would be integrated with a control system to suspend or shut down project operations during or after significant ground shaking (GEO-IAMF#6, GEO-IAMF#8). Shutting down operations temporarily during or after a potentially damaging earthquake would minimize the risk of a moving train encountering structures damaged from earthquake-induced flooding. The train system would be inspected for damage and then returned to service or repaired, if necessary (GEO-IAMF#8). With implementation of project features, project operations would not increase exposure of people to injury or loss of life or of property to damage or destruction beyond current exposure to earthquake-induced flooding. The location and footprint of both project alternatives are similar, especially in comparison to the scale of earthquake-induced flooding; therefore, following the implementation of the project features on both project alternatives, there would be no substantial difference in operations impacts between project alternatives.

CEQA Conclusion

The impact under CEQA would be less than significant because project features would include design methods to minimize secondary seismic hazards (GEO-IAMF#1) and conform to guidelines specified by relevant transportation and building agencies (GEO-IAMF#10). Also, project operations would incorporate monitoring to promote the long-term stability of slopes (GEO-IAMF#2) and early warning systems that would be triggered by strong ground motion (GEO-IAMF#6) and shut down train operations during or after an earthquake (GEO-IAMF#8). Through the application of these project features, the project would not directly or indirectly increase exposure of people to injury or loss of life or property to damage or destruction from secondary seismic hazards during operations, beyond the level people currently experience in the RSA. Therefore, CEQA does not require mitigation.

3.9.6.3 Paleontological Resources

Construction of the project alternatives would result in impacts on paleontological resources. The primary mechanism for adverse impacts on paleontological resources would be ground disturbance (earthwork), which would destroy paleontological resources contained within geologic units. Table 3.9-8 summarizes the distribution of geologic units by subsection in the RSA. Earthwork affecting these geologic units would thus have the potential to destroy significant (i.e., scientifically important) paleontological resources. Once lost, such resources cannot be recovered; impacts are therefore considered permanent. This section describes the potential direct impacts of project construction on paleontologically sensitive geologic units and on paleontological resources for both project alternatives. No indirect impacts (i.e., loss of resources to theft and vandalism resulting from increased public access to paleontologically sensitive areas) on paleontological resources are anticipated.

No Project Impacts

The conditions describing the No Project Alternative are the same as those described in Section 3.9.6.2, Geology, Soils, and Seismicity. Development in the Bay Area to accommodate the population and employment increase would continue under the No Project Alternative, resulting in associated direct temporary and permanent conversion of existing land uses and the potential for ground disturbance in paleontologically sensitive geologic units. Planned projects that could affect paleontological resources include residential, commercial, office, industrial, recreational, and transportation projects. The potential for impacts would depend on the extent of disturbance on paleontologically sensitive geologic units. Many of the proposed residential and mixed-use developments along the project footprint are infill developments with less potential for disturbance of intact paleontological resources. Transportation projects present a greater potential for impacts where they overlap paleontologically sensitive geologic units.

Where future projects involve paleontologically sensitive geologic units, ground disturbance could result in the direct or indirect destruction of unique paleontological resources or sites and associated loss of scientific information. To the extent that ongoing infrastructure and other operations would involve ground disturbance, such operations would also have the potential to result in the direct or indirect destruction of unique paleontological resources or sites and the loss of scientific information. Depending on the extent of the loss, impacts could be significant. However, these projects would be subject to CEQA or NEPA review, or both, and subsequent paleontological mitigation to reduce impacts.

Project Impacts

Construction Impacts

Construction of the project alternatives would consist predominantly of track modifications, relocation of OCS poles, and installation of communication radio towers, four-quadrant gates at at-grade crossings, and perimeter fencing along the right-of-way. Construction would also involve roadway modifications, station modifications, modifications to or construction of new structures, construction of aerial structures (under Alternative B), and construction of the new Brisbane LMF (both alternatives) and additional passing tracks (under Alternative B). Activities associated with constructing this infrastructure include establishing equipment and materials storage areas close to construction sites; demolition of existing structures along El Camino Real to expand the Millbrae Station area; clearing and grubbing; handling, storing, hauling, excavating, and placing fill; possible pile driving; and construction of bridges, viaducts, road modifications, and utility relocations. Construction activities are described in Chapter 2.

Impact GEO#11: Destruction of Paleontological Resources during Construction

Ground-disturbing activities conducted during construction of the project could affect the following geologic units identified as having high or undetermined paleontological potential:

- Colma Formation and Older Quaternary alluvium at the surface and at depth in the San Francisco to South San Francisco Subsection
- Colma Formation and Older Quaternary alluvium at the surface and at depth and Merced Formation at depth in the San Bruno to San Mateo Subsection
- Older Quaternary alluvium at the surface and Santa Clara Formation at depth in the San Mateo to Palo Alto Subsection
- Older Quaternary alluvium at depth in the Mountain View to Santa Clara Subsection
- Older Quaternary alluvium at depth in the San Jose Diridon Station Approach Subsection

The project alternatives would be almost entirely within the existing Caltrain right-of-way. Portions of the alignments that use existing tracks and would not require modifications involving ground disturbance (e.g., trenching, drilling, grading) have no potential to affect paleontological resources. Additionally, much of the existing ground surface in the alignment has been disturbed to varying depths by previous development. Therefore, shallow excavations in these areas would not be anticipated to affect paleontological resources.

Deeper excavations have the potential to affect paleontological resources if native sediments belonging to the Merced Formation, Santa Clara Formation, Colma Formation, or older Quaternary deposits are encountered in the surface or in the subsurface. Excavation activities that may result in direct impacts on paleontologically sensitive geologic units include earthwork related to roadway modifications, station modifications, modifications to or construction of new structures, and construction of the new Brisbane LMF and additional passing track.

Excavations that extend deep enough to encounter paleontologically sensitive geologic units underlying areas mapped as low-potential younger alluvium have the potential to result in adverse impacts on paleontological resources. Surficial activities such as vegetation removal and staging generally do not extend deep enough to affect paleontologically sensitive geologic units.

Alternatives A and B would affect the same paleontologically sensitive geologic units because both project alternatives would be predominantly within the existing Caltrain corridor. The overall construction process would be similar under both project alternatives, resulting in similar potential for impacts on paleontological resources during ground-disturbing activities. Both project alternatives would require similar amounts of excavation, most of which would occur at the site of the Brisbane LMF, the Tunnel Avenue grade separation, and the passing track (under Alternative B). However, construction of Alternative B would require more ground disturbance than Alternative A because of the longer length of track modification and OCS pole relocation, the greater number of station modifications, the construction of a 6-mile-long stretch of additional passing track, and the construction of viaducts in the San Jose Diridon Station Approach Subsection. The additional passing track in Alternative B, which would be constructed on embankment, would require 177,100 cubic yards of cut. Excavations for the passing track would occur in older Quaternary deposits (undetermined to high potential), younger Quaternary deposits (low potential), artificial fill (low potential), and Franciscan Complex (low potential). The younger Quaternary deposits and artificial fill in the passing track area are likely underlain at unknown depths by older Quaternary deposits of undetermined to high paleontological potential and low-potential Franciscan Complex. Construction of viaduct foundations would require deep excavations that would occur in younger Quaternary deposits and artificial fill (low potential) that are likely underlain at unknown depths by older Quaternary deposits (undetermined to high paleontological potential). Construction of Alternative B (Viaduct to Scott Boulevard) would require more ground disturbance than Alternative B (Viaduct to I-880) because of the longer length of the viaduct. The potential for direct or indirect destruction of unique paleontological resources or sites would therefore be greatest for Alternative B (Viaduct to Scott Boulevard) and least for Alternative A. The potential for impacts would increase as the extent of disturbance increases, because fossils are usually found during excavation activities and the chance of finding fossils increases if a large volume of a paleontologically sensitive geologic unit is being exposed. Nevertheless, even activity that is limited in extent could have the potential to result in the loss of scientifically important resources. However, project features include provisions for avoiding loss of scientifically important paleontological resources in areas of high paleontological sensitivity.

To minimize loss of scientifically important resources during construction, the contractor would designate a PRS to be responsible for determining where and when to conduct paleontological resource monitoring prior to any ground-disturbing activities (GEO-IAMF#11) based on the results of a final design review (GEO-IAMF#12). The PRS would select paleontological resource monitors (PRM) based on their qualifications and would determine the scope and nature of their monitoring in accordance with the PRMMP. The PRS would be responsible for developing WEAP training (GEO-IAMF#14), required of all management and supervisory personnel and construction workers involved with ground-disturbing activities before beginning work. The PRS would provide the necessary resources for responding should paleontological resources be found during construction (GEO-IAMF#15). The PRS would document any discoveries, evaluate the potential resource, and assess the significance of the find under the criteria set forth in CEQA Guidelines Section 15064.5.

During construction, paleontological resource monitoring and mitigation measures would be restricted to those construction-related activities that would result in the disturbance of paleontologically sensitive geologic units, as defined in the PRMMP (GEO-IAMF#13). The PRS would prepare and implement a PRMMP, which would define the scope and nature of the monitoring effort and would be reviewed and approved by the Authority. The PRMMP would include a description of when and where construction monitoring would be required; emergency discovery procedures; sampling and data recovery procedures; procedures for the preparation, identification, analysis, and curation of fossil specimens and data recovered; and procedures for reporting the results of the monitoring and mitigation program. The PRMMP would be consistent with SVP (2010) guidelines or their successors for mitigating construction impacts on paleontological resources. The PRMMP would also be consistent with the SVP (1996) conditions for receivership of paleontological collections and any specific requirements of the designated repository for any fossils collected. The PRS would submit the PRMMP to the Authority for review and approval prior to construction (GEO-IAMF#13).

If fossils or fossil-bearing deposits are discovered during construction, regardless of who makes the paleontological discovery (e.g., PRS, PRM, or construction personnel), construction activity in the immediate vicinity of the discovery would cease in order to minimize the potential for resource impacts (GEO-IAMF#15). Both the PRMMP and the WEAP training would clearly specify this requirement. Construction activity may continue elsewhere if it continues to be monitored as appropriate. If someone other than a PRM or the PRS makes the discovery, a PRM or the PRS would immediately be notified to evaluate the find. The PRM would complete construction dailies documenting PRMMP implementation for compliance monitoring. If fossils or fossil-bearing deposits are discovered during construction, the PRS would prepare a final paleontological mitigation report. The report would include dates of fieldwork, results of monitoring, summaries of fossil discoveries and recoveries, fossil analyses, significance evaluations, conclusions, locality forms, and an itemized list of catalogued specimens deposited at the designated repository (GEO-IAMF#13).

CEQA Conclusion

The impact on paleontological resources under CEQA would be less than significant for both project alternatives because the project would require identification and salvage of fossils prior to and during construction. The contractor would designate a PRS for the project (approved by the Authority) who would be responsible for determining where and when to conduct paleontological resources monitoring (GEO-IAMF#11). The PRS would document any discoveries as needed, evaluate the potential resource, and assess the significance of the find under the criteria set forth in CEQA Guidelines Section 15064.5 (GEO-IAMF#12). Paleontological resource monitoring and mitigation measures would be restricted to those construction-related activities that would result in the disturbance of paleontologically sensitive geologic units (GEO-IAMF#13). Construction activity in the immediate vicinity of a paleontological discovery would cease in order to minimize the potential for resource impacts (GEO-IAMF#15). The paleontological resources WEAP training would be provided concurrently with the cultural resources WEAP training (GEO-IAMF#14). These project features would avoid the potential for ground disturbance to directly or indirectly destroy a unique paleontological resource or site or unique geologic feature. Therefore, CEQA does not require mitigation.

Operations Impacts

Operations would include scheduled train travel along the alignment through the Bay Area, inspection and maintenance along the track and railroad right-of-way as well as on the stations, structures, fencing, power system, train control, and communications. Chapter 2 describes operations and maintenance activities. Ground disturbance associated with these activities would be minimal and likely would occur within areas of previous disturbance; therefore, operations-related impacts on paleontological resources are not evaluated further.

3.9.7 Mitigation Measures

There would be no significant impacts on geology, soils, seismicity, or paleontological resources under CEQA under either of the project alternatives. No mitigation measures are required.

3.9.8 Impact Summary for NEPA Comparison of Alternatives

As described in Section 3.1.5.4, the effect of project actions under NEPA are compared to the No Project condition when evaluating the impact of the project on the resource. The determination of effect is based on the context, intensity, and duration of the change that would be generated by construction and operation of the project. Table 3.9-18 compares the project impacts by alternative, followed by a summary of the impacts.

Table 3.9-18 Comparison of Project Alternative Impacts for Geology, Soils, Seismicity, and Paleontological Resources

Impacts	Alternative A	Alternative B
Geology, Soils, and Seismicity		
Impact GEO#1: Construction on Unstable Soils	The project would minimize the potential for loss of life and structural damage from exposure to ground subsidence, landslides, and soft soil by controlling the amount of groundwater withdrawal and stabilizing landslides and soft soil during construction.	Same as Alternative A
Impact GEO#2: Construction on Expansive Soils	The project would minimize the potential for loss of life and structural damage from exposure to expansive soil by treating the soil with additives to reduce shrink-swell potential or excavating and replacing the soil.	Same as Alternative A
Impact GEO#3: Exposure of Concrete and Steel to Corrosive Soils	The project would excavate and replace corrosive soil with noncorrosive soil or use corrosion-resistant materials or coatings, which would minimize the potential for loss of life and structural damage.	Same as Alternative A
Impact GEO#4: Excavation and Grading Impacts on Soil Erosion	Construction of Alternative A would require soil disturbance of 981 acres. The project would require a SWPPP, erosion control measures (stabilizers, mulches, revegetation, and cover exposed work areas with biodegradable geotextiles) during construction, and design that reduces surface water runoff, which would minimize soil erosion and the loss of topsoil.	Construction of Alternative B (Viaduct to I-880) would require soil disturbance of 1,097 acres, and construction of Alternative B (Viaduct to Scott Boulevard) would require soil disturbance of 1,127 acres. The project would implement the same measures as described for Alternative A.
Impact GEO#5: Difficult Excavations due to Shallow Bedrock or Shallow Groundwater	The project would minimize the potential for loss of life and structural damage from excavating in areas with shallow bedrock or shallow groundwater by assessing geotechnical conditions prior to construction and employing appropriate and safe excavation methods.	Same as Alternative A
Impact GEO#6: Construction on Landfills	Construction of the East Brisbane LMF would occur on the site of the former Brisbane Landfill. The project would minimize the potential for injury, loss of life, and structural damage from landfill hazards, including migration and exposure of landfill gas, by using safe construction methods, monitoring for gases, preloading structural areas, and using deep foundations.	The West Brisbane LMF would be constructed approximately 450 feet west of the former Brisbane landfill. The project would minimize the potential for injury, loss of life, and structural damage from subsurface migration of landfill gases by monitoring for gases and following regulatory requirements for construction in an area of potential vapor intrusion.

Impacts	Alternative A	Alternative B
Impact GEO#7: Primary Seismic Hazards during Construction	The project would include design and construction practices to minimize risk from primary seismic hazards. These project features include seismic studies, the implementation of a CMP that includes worker safety protocols for seismic events that could occur during construction, and compliance with guidelines and standards specified by relevant transportation and building agencies. These actions would minimize the potential for loss of life and structural damage from exposure to surface fault rupture during construction.	Same as Alternative A
Impact GEO#8: Secondary Seismic Hazards during Construction	The project would assess geotechnical conditions and employ ground improvement methods and slope reinforcement, which would minimize the potential for loss of life and structural damage from exposure to secondary seismic hazards. The project would also implement a CMP that would address worker safety in the event of an earthquake that triggers flooding.	Same as Alternative A
Impact GEO#9: Primary Seismic Hazards during Operations	The project would apply seismic design standards in the structural design, use early warning systems triggered by strong ground motion, and shut down train operations during or after an earthquake, if necessary. These actions would minimize the potential for loss of life and structural damage from exposure to surface fault rupture.	Same as Alternative A
Impact GEO#10: Secondary Seismic Hazards during Operations	The project would assess geotechnical conditions and employ ground improvement methods and slope reinforcement, which would minimize the potential for loss of life and structural damage from exposure to secondary seismic hazards. The project would also employ an earthquake early warning system to stop operations, if necessary.	Same as Alternative A

Impacts	Alternative A	Alternative B
Paleontological Resources		
Impact GEO#11: Destruction of Paleontological Resources during Construction	Construction could affect four paleontologically sensitive geologic units with the potential to contain previously unknown paleontological resources at the surface or at depth.	Similar to Alternative A; however, more ground disturbance would be required in areas mapped at the surface as having undetermined to high paleontological potential, resulting in increased potential for permanent impacts. Alternative B (Viaduct to Scott Boulevard) would require greater ground disturbance than Alternative B (Viaduct to I-880) in areas mapped at the surface as having undetermined to high paleontological potential in the subsurface, resulting in increased potential for permanent impacts.

CMP = construction management plan
LMF = light maintenance facility
SWPPP = stormwater pollution prevention plan

Construction or modification of roadway and pedestrian underpasses, underground utilities, and bridges and culverts under both project alternatives would require temporary dewatering in areas of shallow groundwater. Alternative B is anticipated to result in more temporary dewatering activities than Alternative A, primarily because more bridges and culverts would be modified to accommodate the passing track. Under both project alternatives, localized ground subsidence associated with temporary construction-related dewatering would be avoided through implementation of conventional engineering methods. These measures would include monitoring and controlling the amount of groundwater withdrawal from the project, by reinjecting groundwater at specific locations if necessary, or by using alternate foundation designs to offset the potential for settlement.

Neither project alternative would require construction in areas with steep slopes susceptible to risks of landslides, except near San Bruno Mountain. However, near San Bruno Mountain, only minor track shifts would occur, which would be within the existing Caltrain rights-of-way and would have no effect on existing slopes that are susceptible to landslides. Construction on soft soils would occur along much of the alignment, and would affect construction of the Brisbane LMF under both project alternatives because both the East and West Brisbane LMF would be located on artificial fill underlain by Young Bay Mud. Prior to construction, the Authority would assess site conditions to determine the most appropriate engineering solutions to addressing unstable soils, in accordance with relevant design guidelines and standards (GEO-IAMF#10). The design-build contractor would prepare a CMP prior to construction that would include design measures to minimize or avoid exposure of people or structures to impacts from unstable soil. Design measures would include controlling the amount of groundwater withdrawal to minimize localized subsidence, as well as reinforcement, improvement, or removal and replacement of landslides and soft soil (GEO-IAMF#1).

The CMP would also include methods to minimize or avoid exposure of people or structures to impacts from expansive and corrosive soils, which would be encountered along much of the alignment under both project alternatives. Expansive soil would be mixed with additives to reduce shrink-swell potential or would be excavated and replaced. Corrosive soils would be removed, buried structures would be designed for corrosive conditions, and corrosion-protected materials would be used (GEO-IAMF#1). As a result of the project features, project construction would not increase exposure of people to loss of life or structures to destruction due to expansive or corrosive soils. These project features would be implemented on both project alternatives, so there would be no substantial difference in construction impacts between project alternatives.

Construction of both project alternatives would require grading, excavation, vegetation clearing, operation of heavy equipment, and other activities that would disturb, destabilize, and stockpile soil, increasing the potential for soil erosion. The amount of soil disturbance during construction is similar for both of the project alternatives—Alternative A is anticipated to require disturbance of 981 acres of soil, whereas construction of Alternative B (Viaduct to I-880) is anticipated to require disturbance of 1,097 acres and Alternative B (Viaduct to Scott Boulevard) is anticipated to require disturbance of 1,127 acres. Soil disturbance under Alternative B (both viaduct options) is greater primarily because of the wider footprint along the proposed passing track and larger temporary disturbance areas associated with viaduct construction, and the associated soil disturbances within these footprints. Project features would minimize soil erosion from construction of the project through the adoption of BMPs that protect exposed soil and reduce runoff. The BMPs would be documented and implemented according to a CMP and a SWPPP (GEO-IAMF#1). Standard construction practices and BMPs would be effective in reducing wind and water erosion potential because they would provide a barrier between exposed soils and erosive forces or lessen the degree of erosive forces. As a result of these project features, construction would not result in substantial soil erosion under either project alternative.

Prior to construction, the design-build contractor would prepare a CMP that would specify the details of how the project would minimize or avoid exposure of people to impacts from difficult excavation conditions, such as shallow bedrock or shallow groundwater (GEO-IAMF#1). The contractor would develop safety procedures and guidelines for the use of potentially dangerous excavation methods and equipment. Geotechnical investigations would help to identify the areas where shallow groundwater or potentially difficult-to-excavate rock would be encountered during construction. The contractors may use temporary dewatering with deep groundwater wells and well points that lower the water level; sheet pile wall systems to stabilize the soil; or 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. Project design and construction would conform to guidelines specified by relevant transportation and building agencies and codes that require Authority contractors to account for soil and geotechnical properties during design and construction and thus minimize or avoid risks associated with shallow bedrock or shallow groundwater (GEO-IAMF#10). As a result of the project features, construction would not increase exposure of people to loss of life or property to destruction as a result of shallow bedrock or shallow groundwater. The project features would be implemented on both project alternatives; there would be no substantial difference in impacts between project alternatives.

Construction of the East Brisbane LMF under Alternative A would require significant earthwork cut and fill on the site of the former Brisbane Landfill, while construction of the West Brisbane LMF under Alternative B would require similar construction activities approximately 450 feet west of the former Brisbane Landfill. Construction of Alternative A would require the implementation of project features at the landfill to minimize risks associated with the release of flammable gases and the potential for ground settlement due to the compressibility of buried refuse and decomposition of organic materials. Prior to construction of Alternative A, the contractor would prepare a CMP that would include gas monitoring during construction. The contractor would follow the Occupational Safety and Health Administration, U.S. Environmental Protection Agency, and Department of Toxic Substances Control regulatory requirements for construction on landfills, thereby reducing risks associated with landfill gas. In addition, the project would use safe and explosion-proof equipment as well as testing for gases regularly and installing gas monitoring and venting systems (GEO-IAMF#3). Structures founded on a landfill would be constructed using the latest California Building Code, requiring the contractor to account for ground settlement resulting from the compression or decomposition of landfill refuse (GEO-IAMF#10). Contractors could employ ground improvement such as preloading to reduce future ground settlement or using deep foundations systems such as piles to transfer the weight of a building to soil/rock below the refuse (GEO-IAMF#1). Because of these project features, construction of Alternative A would not result in substantial risk of loss of life or destruction of property as a result of exposure to landfill gas or ground settlement from compression or decomposition of landfill refuse. Construction of Alternative B would not expose people or structures to risks associated with construction on landfills.

Prior to construction, project features would include a three-tiered analysis to characterize the potential for hazardous fault displacements (Authority 2014). First, an initial screening would identify potentially hazardous fault zones. Second, potentially hazardous fault zones would be further evaluated to determine if they meet the criteria to be considered hazardous fault zones. Third, estimates of fault displacements at hazardous fault zones would be made for purposes of design. The design-build contractor would prepare and implement a CMP that would include design measures to minimize or avoid exposure of people or structures to effects from surface fault rupture, including worker safety protocols for seismic events that could occur during construction (GEO-IAMF#1). The design measures would conform to relevant guidelines specified by transportation and building agencies and codes (GEO-IAMF#10) requiring contractors to account for seismic hazards during design and construction. The project would incorporate a ground rupture early warning system, motion sensing instruments, and a train control system to shut down operations during or after a potentially damaging earthquake (GEO-IAMF#6, GEO-IAMF#8). The train system would be inspected for damage and then returned to service or repaired, if necessary (GEO-IAMF#8). Because of these project features, neither project construction nor operations would increase exposure of people or structures to potential loss of life, injuries, or structural destruction beyond current exposure to surface fault rupture or ground shaking in the area. These project features would be implemented on both project alternatives, so there would be no substantial difference in impacts between project alternatives.

Project features would minimize risks to people and property associated with secondary seismic hazards (i.e., liquefaction, lateral spreading, earthquake-induced landslides, and earthquake-induced dam failure). The design-build contractor would assess geotechnical conditions and employ ground improvement methods, such as stone columns, deep dynamic compaction, cement deep-soil mixing, jet grouting, or excavating and replacing liquefiable soil with engineered fill (GEO-IAMF#1). Landslide stability would be assessed using the most recently updated Authority seismic design criteria (GEO-IAMF#7), and the contractor would include design measures such as structural solutions (e.g., tie backs, soil nails, retaining walls, debris barriers) or earthwork solutions (e.g., ground improvement, regrading/rebuilding of slopes) to minimize or avoid the effects of earthquake-induced landslides (GEO-IAMF#1). The CMP would also include evacuation plans as well as earthquake response training for workers. Conforming to guidelines specified by relevant transportation and building agencies and codes would require contractors to account for drainage patterns and topography during design and construction and thus be able to establish safe evacuation areas in the event of an earthquake (GEO-IAMF#10). The project would incorporate an earthquake early warning system, motion-sensing instruments, and a train control system to shut down project operations during or after a significant earthquake so that the system could be inspected for damage and then returned to service or repaired, if necessary (GEO-IAMF#6, GEO-IAMF#8). Project construction and operations would not increase exposure of people to injury or loss of life, or property to damage or destruction beyond current exposure to liquefaction, lateral spreading, earthquake-induced landslides, and earthquake-induced flooding. The project features would be implemented on both project alternatives; there would be no substantial difference in impacts between project alternatives.

Project features would address paleontological resources monitoring and mitigation, discovery procedures, halting construction when paleontological resources are found, and training (GEO-IAMF#11, GEO-IAMF#12, GEO-IAMF#13, GEO-IAMF#14, GEO-IAMF#15). Both project alternatives would affect the same paleontologically sensitive geologic units and would employ similar construction, operations, and maintenance activities, resulting in similar potential for impacts on paleontological resources during ground-disturbing activities. However, the passing track under Alternative B would potentially affect more paleontological resources than Alternative A because of the additional excavation required in paleontologically sensitive geologic units. In addition, Alternative B (Viaduct to Scott Boulevard) would potentially affect more paleontological resources than Alternative B (Viaduct to I-880) because of the additional length of excavation required in paleontologically sensitive geologic units in the subsurface of the San Jose Diridon Station Approach Subsection.

3.9.9 CEQA Significance Conclusions

As described in Section 3.1.5.4, the impacts of project actions under CEQA are evaluated against thresholds to determine whether a project action would result in no impact, a less-than-significant impact, or a significant impact. Table 3.9-19 identifies the CEQA significance determinations for each impact discussed in Section 3.9.6.

Table 3.9-19 CEQA Significance Conclusions and Mitigation Measures for Geology, Soils, Seismicity, and Paleontological Resources

Impacts	Impact Description and CEQA Level of Significance before Mitigation	Mitigation Measure	CEQA Level of Significance after Mitigation
Geology, Soils, and Seismicity			
Impact GEO#1: Construction on Unstable Soils	Less than significant for both project alternatives: The project would not directly or indirectly increase exposure of people to injury or loss of life or property to damage or destruction from ground subsidence, landslides, and soft soil by implementing standard geotechnical engineering practices.	No mitigation measures are required	N/A
Impact GEO#2: Construction on Expansive Soils	Less than significant for both project alternatives: The project would not directly or indirectly increase exposure of people to injury or loss of life or property to damage or destruction from expansive soil by removing it or treating it with soil additives.	No mitigation measures are required	N/A
Impact GEO#3: Exposure of Concrete and Steel to Corrosive Soils	Less than significant for both project alternatives: The project would not directly or indirectly increase exposure of people to injury or loss of life or property to damage or destruction from corrosive soil by removing it and using corrosion-protected materials for buried structures.	No mitigation measures are required	N/A
Impact GEO#4: Excavation and Grading Impacts on Soil Erosion	Less than significant for both project alternatives: There would be no effect on the productivity of farming in the area because no active farming occurs in the Project Section. The project would not result in substantial soil erosion or the loss of topsoil by using standard erosion control methods.	No mitigation measures are required	N/A

Impacts	Impact Description and CEQA Level of Significance before Mitigation	Mitigation Measure	CEQA Level of Significance after Mitigation
Impact GEO#5: Difficult Excavations due to Shallow Bedrock or Shallow Groundwater Conditions	Less than significant for both project alternatives: The project would not render a currently stable geologic unit or soil unstable to a degree that it would directly or indirectly increase exposure of people to injury or loss of life or property to damage or destruction associated with excavating in areas with shallow bedrock or shallow groundwater by using standard construction safety practices.	No mitigation measures are required	N/A
Impact GEO#6: Construction on Landfill	Less than significant for Alternative A: The project would not directly or indirectly provide a route of exposure for landfill gas or increase exposure of people to injury or loss of life or property to damage or destruction from landfill gas associated with construction of the East Brisbane LMF on the former Brisbane Landfill through the use of safe construction methods, monitoring for gases, preloading structural areas, and the use of deep foundations. Less than significant for Alternative B: The West Brisbane LMF would be built approximately 450 feet west of the former Brisbane Landfill. Through the application of project features the project would not directly or indirectly provide a route of exposure for landfill gas or increase exposure of people to injury or loss of life or property to damage or destruction from landfill gas.	No mitigation measures are required	N/A
Impact GEO#7: Primary Seismic Hazards during Construction	Less than significant for both project alternatives: The project would not directly or indirectly increase exposure of people to injury or loss of life or property to damage or destruction from surface fault rupture and ground shaking during construction by using standard construction safety practices.	No mitigation measures are required	N/A

Impacts	Impact Description and CEQA Level of Significance before Mitigation	Mitigation Measure	CEQA Level of Significance after Mitigation
Impact GEO#8: Secondary Seismic Hazards during Construction	Less than significant for both project alternatives: The project would not directly or indirectly increase exposure of people to injury or loss of life or property to damage or destruction from liquefaction, lateral spreading, earthquake-induced landslides, and earthquake-induced flooding by using ground improvement, structural reinforcement, removal of unstable material, and standard construction safety practices.	No mitigation measures are required	N/A
Impact GEO#9: Primary Seismic Hazards during Operations	Less than significant for both project alternatives: The project would not directly or indirectly increase exposure of people to injury or loss of life or property to damage or destruction due to surface fault rupture and ground shaking by using an earthquake early warning system, using motion-sensing instruments, and shutting down operations during an earthquake.	No mitigation measures are required	N/A
Impact GEO#10: Secondary Seismic Hazards during Operations	Less than significant for both project alternatives: The project would not directly or indirectly increase exposure of people to injury or loss of life or property to damage or destruction due to liquefaction, lateral spreading, earthquake-induced landslides, and earthquake-induced flooding by improving or removing liquefiable soil or unstable soil/rock during construction and using an earthquake early warning system, using motion sensing instruments, and shutting down operations during an earthquake.	No mitigation measures are required	N/A
Paleontology			
Impact GEO#11: Destruction of Paleontological Resources during Construction	Less than significant for both project alternatives: The project would avoid the potential for destruction of a unique paleontological resource or site through paleontological resources monitoring and mitigation; discovery procedures; halting construction when paleontological resources are found; and training.	No mitigation measures are required	N/A

CEQA = California Environmental Quality Act
LMF = light maintenance facility
N/A = not applicable