2.10 Geology/Soils/Seismic/Topography

2.10.1 Regulatory Setting

For geologic and topographic features, the key federal law is the Historic Sites Act of 1935, which establishes a national registry of natural landmarks and protects "outstanding examples of major geological features." Topographic and geologic features are also protected under the California Environmental Quality Act (CEQA).

This section also discusses geology, soils, and seismic concerns as they relate to public safety and project design. Earthquakes are prime considerations in the design and retrofit of structures. Structures are designed using Caltrans' Seismic Design Criteria (SDC). The SDC provides the minimum seismic requirements for highway bridges designed in California. A bridge's category and classification will determine its seismic performance level and which methods are used for estimating the seismic demands and structural capabilities. For more information, please see the Caltrans' Division of Engineering Services, Office of Earthquake Engineering, Seismic Design Criteria.

2.10.2 Affected Environment

This section discusses the existing geologic and soils conditions within the Study Area and provides an analysis of the potential impacts of the proposed project that are related to geology and soils. This section also addresses the potential for structural damage to project facilities due to the local geology underlying the project site, as well as slope stability, ground settlement, soils, grading, and seismic conditions. This section summarizes information provided in the *Revised District Preliminary Geotechnical Report* (2017).

2.10.2.1 Local Geology, Topography, and Soils

The I-5 project segment is located within the southeastern part of the Los Angeles Basin (Basin) called the Tustin Plain, between Loma Ridge on the northeast and the San Joaquin Hills on the southwest. The Tustin Plain is a low-lying plain between the steeper slopes of the Loma Ridge and the San Joaquin Hills. The southern Tustin Plain slopes westerly from elevations of approximately 200 to 300 feet (ft) along Loma Ridge to approximately 50 ft near the northern end of the San Joaquin Hills. The Basin floor rises to as much as 100 ft across the Newport Inglewood Structural Zone (NISZ), which is defined as one of several, large predominantly right-lateral strike-slip fault zones that parallel the San Andreas Fault in southern California.

The ground surface surrounding the I-5 project segment is approximately 220 ft in elevation at the southeast end and approximately 130 ft in elevation at the northwest end. Elevations reach a low point near Jamboree Road at 75 ft elevation along the north-central portion of the I-5 project segment. The overall relief within the I-5 project segment consists of an increase in elevation trending southeast along the corridor.

The Tustin Plain consists of clays, silts, sands, and gravel and sediments composed of Holocene-age alluvium and colluvium. The regional topography suggests that these materials were derived primarily from Loma Ridge via Peters Canyon Wash and other minor washes (e.g., Borrego Wash). These young alluvial units overlie Pleistocene- and Pliocene-age sediments of the Lakewood, San Pedro, and Pico Formations. Regional geological and groundwater investigations indicate these formations are several thousand feet thick and overlie early Tertiary- and Cretaceous-age sedimentary rocks at depth. Crystalline basement rocks lie approximately 6,000 ft below the site area.

Based on Log-of-Test-Borings (LOTB) samples that were taken from locations along I-5 between I-405 and SR-55 (those samples were derived from plans for bridges that have since been built), soils along the I-5 project segment are discussed as follows:

- **Zone A: From the I-405 Interchange to the Yale Avenue Overcrossing.** The groundline along I-5 descends from approximately +228 ft to +130 ft in elevation within this zone. Subsurface soils are predominantly silty clay and sandy silt near the ground surface that are underlain by sandy soils consisting of clayey sand, silty sand and sand to the maximum depth explored. Consistency of the soils increases with depth, typically from stiff-to-very-stiff for clay soils and medium dense at shallow depths to very dense at deeper depths for sandy soils.
- **Zone B: North of Yale Avenue Overcrossing to Peters Canyon Channel.** The groundline along I-5 descends from approximately +130 ft to approximately +80 ft in elevation within this zone. Subsurface soils are predominantly sandy consisting of clayey sand, silty sand, and sand. Consistency of the soils increases with depth, typically from loose at shallow depths to very dense at deeper depths.
- **Zone C: North of Peters Canyon Channel to Tustin Ranch Road Overcrossing.** The groundline change along I-5 is less pronounced within this zone; the ground elevation increases from approximately +80 ft to approximately +84 ft in elevation. Subsurface soils at shallow depths are predominantly sandy clay, clayey silt, and sandy silt. This layer is underlain by predominantly sandy

soils, including clayey sand, silty sand, sand, and gravel with occasional layers of silty clay and sandy silt. Consistency of the soils increases with depth, typically from medium-stiff to very-stiff for clay soils and loose at shallow depths to very dense at deeper depths for sandy soils.

- **Zone D: North of Tustin Ranch Road to SR-55.** The groundline along I-5 rises from approximately +84 ft to approximately +135 ft in elevation within this zone. Subsurface soils are predominantly sandy consisting of silty sand, sand, and gravel. Consistency of the soils increases with depth, typically from medium dense at shallow depth to very dense at deeper depths.

I-5 traverses a generally flat, developed area with no unique or unusual geologic features within or adjacent to the I-5 project segment.

2.10.2.2 Geologic Hazards

Geological hazards relevant to the I-5 project segment include seismic ground shaking, localized soil liquefaction, and seismic settlement. The following irrelevant geologic hazards for the I-5 project segment are identified; however, they are not discussed further in this section:

- **Tsunami and Seiches:** Seiches are large waves generated in enclosed bodies of waters, such as lakes, in response to ground shaking. Tsunamis are waves generated in large bodies of water as a result of fault displacement or major ground movement. There are no enclosed bodies of water near the project site and the Pacific Ocean is approximately 4 miles (mi) west of the I-5 project segment. As a result, the existing potential risks to I-5 related to tsunamis and seiches are considered negligible.
- **Seismically-Induced Landslides:** There is no clustering or alignment of earthquakes in proximity to the project area. There are fewer earthquakes in the Tustin Plain-western Santa Ana Mountains region than anywhere else in the Los Angeles Basin area. This apparent lack of earthquake activity suggests that the project area is tectonically stable and suggests that there are no unrecognized active faults at the site. Additionally, the City of Irvine's Open Space Conservation Element, the City of Tustin's Safety Elements and Map of Localities in Los Angeles Region were reviewed and indicated that topography in the project area is flat and does not contain known landslide areas (City of Tustin 2013; City of Irvine 2015; California 1978).
- **Rock Falls:** The City of Irvine General Plan (August 2015) and the City of Tustin General Plan (October 2013) do not document rock fall areas. As previously

mentioned (Section 2.10.2.1), the project area consists of flatland, and geologic hazards, such as landslide areas as a result of steep slopes, have not been mapped in the project area. Therefore, rock fall hazards are unlikely to occur in the project area.

- **Soil Subsidence:** The Open Space and Conservation Element for the City of Irvine (2015) identifies one location, the Lomas Ridge, as an area with the potential for soil subsidence. The Lomas Ridge does not intersect the project area and, therefore, soil subsidence is unlikely to occur in the project area.
- **Non-Seismically Induced Earth Movement:** Unstable geologic formations, identified in Figure D-3 in the City of Irvine's Seismic Element (2015), occur outside of the project area. Therefore, non-seismically induced earth movement is unlikely to occur in the project area.
- **Volcanic Hazards:** There are no active, potentially active, or inactive volcanoes in Orange County. Therefore, volcanic hazards are unlikely to affect the project area.
- **Economical Resources/Mineral Hazards:** The Cities of Irvine and Tustin General Plans and Map of the Aggregate Sustainability in California[1] do not identify economical resources/mineral resources in the project area. Therefore, economical resources/mineral resources are unlikely to be affected or be hazardous to the project area.

There are no known active surface faults within the project limits so the potential for ground rupture is considered low. The nearest active or potentially active fault is located approximately 3.4 mi from the I-5 project segment; as a result, moderate-to-intense ground shaking should be anticipated within the I-5 project segment in the event of an earthquake. Faulting and seismicity is discussed in more detail below.

Some near-surface alluvial sediments within the I-5 project segment are susceptible to liquefaction due to moderate-to-intense ground shaking and historical groundwater levels ranging from 10 to 40 ft below the ground surface. The potential for liquefaction is discussed in more detail later in this section.

[1] California Geological Survey. Map of Aggregate Sustainability in California. 2012. Website: http://www.conservation.ca.gov/cgs/information/publications/ms/Documents/MS_52_2012.pdf (accessed August 7, 2017).

Faulting and Seismicity

The I-5 project segment is characterized by relatively flat-lying Quaternary strata overlying shallow to moderately dipping and faulted Tertiary-Cretaceous sedimentary and volcanic rocks. There are no mapped active faults crossing the I-5 project segment, and no Alquist-Priolo Earthquake Fault Zones have been identified in the project area. The closest major active or potentially active surface faults are the San Joaquin Hills Blind Thrust Fault, the Whittier Fault, and the Newport-Inglewood Fault. The San Joaquin Hills Blind Thrust Fault is located beneath the San Joaquin Hills, as it is believed to have created the uplift within the hills as a fold-and-thrust belt. As a result, the San Joaquin Hills Blind Thrust Fault is located 2.5 mi from the project area, potential for surface rupture is low. The nearest mapped Quaternary fault is the Pelican Hill Fault; however, this is a minor feature that is overshadowed by the Newport-Inglewood Fault. The Pelican Hill Fault is located approximately 6.5 mi southwest of the nearest portion of the I-5 project segment. The Whittier Fault extends northwesterly along the eastern flank of the Santa Ana Mountains and is located approximately 13 mi northeast of the nearest point along the I-5 project segment. The nearest substantial local sources of earthquakes and associated information are summarized in Table 2.10.1.

Table 2.10.1: Local Fault Data

Fault	Fault Type	Maximum Earthquake Magnitude	Slip Rate (mm/yr)	Age	Approximate Distance from I-5/ Yale Avenue to Fault (miles)
San Joaquin Hills	R	7.0	6.0	Late Quaternary	2.5
Pelican Hill	SS	6.3	0.1	Late Quaternary	7.2
Newport Inglewood Fault Zone (South Los Angeles Basin Section-Southern)	SS	7.2	1.0	Holocene	8.1
Newport-Inglewood (Offshore)	SS	6.9	1.0	Holocene	11.0
Whittier	SS	7.7	5.0	Holocene	13.2
Compton	R	6.9	0.9	Holocene	14.1

Source: *Revised District Preliminary Geotechnical Report* (2017)
I-5 = Interstate 5
mm/yr = millimeters per year
R = Reverse
SS = Strike Slip

The I-5 project segment is located in a seismically active region. Historical epicenter maps show widespread seismicity throughout the Los Angeles basin. Although historical earthquakes occur in proximity to known faults, they are difficult to directly

associate with mapped faults. Part of this difficulty is due to the fact that the Los Angeles Basin is underlain by several subsurface thrust faults (blind faults). Earthquakes in the region occur primarily as loose clusters along the NISZ, along the southern margin of the Santa Monica Mountains, the southern margin of the Santa Susana and San Gabriel Mountains, and in the Coyote Hills-Puente Hills area.

There is no clustering or alignment of earthquakes in proximity to the I-5 project segment. There are fewer earthquakes in the Tustin Plain-western Santa Ana Mountains region than anywhere else in the Los Angeles Basin area. This apparent lack of earthquake activity suggests that the I-5 project segment is tectonically stable and suggests that there are no unrecognized active faults at the site.

Peak ground acceleration (PGA) is a measurement of maximum ground acceleration in a particular area and is an important factor for structural engineering against earthquake damage for things such as roads, bridges, and buildings. It can be described as how hard the ground may shake in a given geographic area based on several factors, such as the distance from an active fault, the maximum expected earthquake from that fault, and the underlying geologic units. The PGAs at the southern project limit, continuing north until the State Route 133 (SR-133) and I-5 interchange is estimated to be higher than 0.6g, whereas the remainder of the project area is below 0.6g.[1] All structures associated with the Build Alternative will be designed to incorporate appropriate design measures to address potential effect associated with PGA during seismic events.

Groundwater

The potential for liquefaction within the I-5 project segment was determined based on groundwater levels near the ground surface. Groundwater encountered during drilling is discussed as below:

- **Zone A: From the I-405 Interchange to the Yale Avenue Overcrossing.** Groundwater was encountered during drilling between Alton Parkway and Sand Canyon Avenue at approximately 60 to 80 ft below grade between 1953 and 1988. Between Jeffrey Road and Yale Avenue, groundwater was encountered during drilling at approximately 20 to 35 ft below grade between 1980 and 1988.

[1] "g" is a common value of acceleration equal to 32 feet/second^2 (ft/sec^2).

- **Zone B: North of the Yale Avenue Overcrossing to Peters Canyon Channel.** Groundwater was encountered during drilling between 10 and 20 ft below grade between 1972 and 1988.
- **Zone C: North of Peters Canyon Channel to the Tustin Ranch Road Overcrossing.** Groundwater was encountered during drilling between 10 and 25 ft below grade between 1953 and 2008.
- **Zone D: North of Tustin Ranch Road to SR-55.** Groundwater was encountered during drilling at Redhill Avenue between 25 and 45 ft below grade between 1953 and 1988. Groundwater was not encountered in the exploratory borings performed at Newport Avenue which extended as deep as 80 ft below grade.

Based on information from the California Geological Survey (CGS), the highest historical groundwater along the I-5 project segment is summarized below:

- **Between the I-405 and the Jeffrey Road Overcrossing:** Historical high groundwater depth is 40 ft or greater;
- **Between the Jeffrey Road Overcrossing and the Culver Drive Undercrossing:** Historical high groundwater depth rises from approximately 20 ft to 40 ft below the ground surface;
- **Between the Culver Drive Undercrossing and the Tustin Ranch Road Overcrossing:** Historical high groundwater depth is between 10 and 20 ft below ground; and
- **Between the Tustin Ranch Road Overcrossing and SR-55:** Historical high groundwater depth drops from 10 to 20 ft to 40 ft or greater.

Historic groundwater information showed that depth of groundwater decreased from the southern to the central project areas and then increased from the central to the northern project areas.

Liquefaction Potential and Seismic Settlement

Based on the State CGS Seismic Hazard Maps of the El Toro and Tustin Quadrangles, some near-surface alluvial sediments within the I-5 project segment are susceptible to liquefaction due to moderate to intense ground shaking and historical groundwater levels ranging from 10 ft to 40 ft below ground surface.

Site soils north of Jeffrey Road are susceptible to liquefaction. Results of the liquefaction analyses indicate that the liquefaction potential is low for soils within Zones A, C, and D. Some of the as-built borings within Zone B show the presence of

potentially liquefiable soils; however, the liquefiable zones are localized and not continuous across the entire Zone B.

2.10.2.3 Contaminated Soils

As described in detail in Section 2.12, Hazardous Waste/Materials, aerially deposited lead (ADL) is generally encountered in unpaved areas (or formerly unpaved areas) adjacent to older roads, primarily as a result of lead deposition from historical vehicle emissions. Because the I-5 alignment has been used during periods when leaded gasoline was still in use, the adjacent unpaved surficial soils may contain ADL. In addition, based on the historical agricultural uses in the Study Area, persistent pesticides may remain in soils in the Study Area including along I-5. Other potential areas of soil contamination associated with individual land uses adjacent to I-5 are discussed in Section 2.12, Hazardous Waste/Materials.

2.10.3 Environmental Consequences

2.10.3.1 Temporary Impacts

Build Alternative (Alternative 2A and Alternative 2B [Preferred Alternative])

The potential temporary impacts of the Build Alternative related to geotechnical hazards and resources would be similar along the I-5 project segment and would differ only as a result of improvements being provided in slightly different areas under the Build Alternative. Those impacts are discussed generally in this section and are summarized by alternative in the following sections.

Soil Erosion

Construction of the Build Alternative would temporarily disturb soil outside the project footprint but within the freeway rights-of-way, primarily in the trample zone around work areas, heavy equipment traffic areas, and material laydown areas. Construction activities in temporary construction easements (TCEs) outside the freeway right-of-way would also temporarily disturb soils in those areas. Excavated soil in the construction areas would be exposed and, as a result, there would be an increased potential for soil erosion during construction compared to existing conditions. During a storm event, soil erosion could occur at an accelerated rate.

During all construction activities for the Build Alternative, the construction contractor will be required to adhere to the requirements of the General Construction Permit and to implement erosion and sediment control best management practices (BMPs) specifically identified in the project Storm Water Pollution Prevention Plan (SWPPP)

to keep sediment from moving off site into receiving waters and impacting water quality. Refer to Section 2.9, Water Quality and Storm Water Runoff, for additional discussion regarding construction-related water quality issues and mitigation, including BMPs.

Worker safety hazards resulting from erosion during construction of the Build Alternative would be minimized based on implementation of the requirements in the General Construction Permit and erosion and sediment control BMPs in the SWPPP.

Ground Motion

Construction activities could be affected by ground motion from seismic activities. Possible ground rupture, liquefaction, and slumping or slope failure could occur in areas with artificial fill if an earthquake were to occur during construction. Implementation of safe construction practices and compliance with Caltrans and the California Division of Occupational Safety and Health (Cal-OSHA) safety requirements would minimize the impacts to worker safety during construction activities.

Hazardous Waste

Disturbance of unpaved areas adjacent to the I-5 mainline and ramps and the arterial streets within the project disturbance footprint could disturb ADL and pesticides in the soils, if present. Refer to the previously mentioned Section 2.12, Hazardous Waste/Materials, for discussion of the potential effects associated with disturbance of soils containing ADL and pesticides during construction of the Build Alternative and the project features addressing those potential effects.

No Build Alternative

Under the No Build Alternative, the temporary construction-related impacts discussed above for the Build Alternative would not occur because there would be no construction of project improvements on I-5 under this alternative.

2.10.3.2 Permanent Impacts

Build Alternative (Alternative 2A and Alternative 2B [Preferred Alternative])

The potential permanent impacts of the Build Alternative related to geotechnical issues and resources along the I-5 project segment would be similar and would differ only as a result of the improvements being provided in slightly different areas under Alternative 2A and Alternative 2B (Preferred Alternative). Those impacts are

discussed generally in this section and are summarized by alternative in the following sections.

Local Geology, Topography, and Soils

The Build Alternative would not result in permanent substantive changes to the topography in the project area because the improvements would generally be constructed at or close to the same grade as the existing facility.

As discussed in Section 2.10.2.1, soils within the Study Area are predominantly clayey from I-405 to the Yale Avenue Overcrossing and from Peters Canyon Channel to the Tustin Ranch Road Overcrossing and are predominantly sandy from the Yale Avenue Overcrossing to Peters Canyon Channel and from North Tustin Ranch Road to SR-55. The sandy soils are primarily silty sand, which are not considered to be expansive. The clayey soils consist of sandy and clayey silt and silty clay; the corresponding expansion potential is considered to be moderate to high. Design and construction of the proposed improvements would adhere to the Caltrans *Highway Design Manual* (HDM) (December 2016) and other required standards, and recommendations from the Structure Foundation Report and the Geotechnical Design Report, as included in Project Feature PF-GEO-1.

PF-GEO-1 **Geotechnical Investigation.** During the Plans, Specifications, and Estimates (PS&E) phase, a detailed geotechnical investigation will be conducted by qualified geotechnical personnel to assess the geotechnical conditions at the project area. The geotechnical investigation will include exploratory borings to investigate site-specific soils and conditions and to collect samples of subsurface soils for laboratory testing. Those soil samples will be tested to evaluate liquefaction potential, collapsibility potential, stability, and corrosion potential. The project-specific findings and recommendations of the geotechnical investigation will be summarized in a Structure Foundation Report and a Geotechnical Design Report to be submitted to the California Department of Transportation (Caltrans) for review and approval. Those findings and recommendations will be incorporated in the final design of the Build Alternative.

Adherence to recommendations within these reports would substantially reduce the geologic risks to below a level of significance. In addition, surficial soils that are sandy can be susceptible to soil erosion produced by running water and accelerated

erosion on steep slopes. The clayey surficial soils are expected to expand when wet, and crack upon drying. Cracking allows infiltration of water from storms and irrigation, ultimately causing loosening of the surficial soils. This results in an increase of soil erodibility. Revegetation of graded slopes specified in Project Feature PF-GEO-2 will be performed prior to construction that would minimize the soil erodibility.

PF-GEO-2 **Revegetation.** Prior to construction, revegetation of graded slopes should be performed to minimize erosion, and runoff should be diverted from each slope face using earthen berms and/or concrete swales at the top of each slope.

Additionally, Section 2.9, Water Quality, contains additional project features related to soil erosion, including BMPs; and Section 2.12, Hazardous Waste/Materials, contains additional project features related to hazardous wastes and materials.

Faulting and Seismicity, and Groundwater

Since liquefaction potential within Zones A, C, and D is anticipated to be low, liquefaction-induced (seismic) settlement of on-site soils at these zones is also anticipated to be minor. Based on preliminary calculations, the maximum liquefaction-induced settlement within Zone B is expected to be less than 2 inches.

Based on the preliminary plans, the majority of fill placement for embankment construction is expected to be minor (5 ft or less in height). For taller embankment fills, ground settlements were estimated based on the subsurface soils at these locations and the proposed maximum height of fill.

No Build Alternative

Under the No Build Alternative, the permanent impacts discussed above for the Build Alternative would not occur because none of the permanent I-5 improvements provided in the Build Alternative would be implemented and operated under this alternative.

2.10.4 Avoidance, Minimization, and/or Mitigation Measures

The Preferred Alternative will incorporate the project features outlined in Section 2.10.3.2 that will address potential impacts. No avoidance, minimization, and/or mitigation measures are required.

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