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 the California Department of Transportation (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 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 *Preliminary Geologic Study* (February 2023).

2.10.2.1 Local Geology, Topography, and Soils

The proposed Project is located within the Peninsular Ranges Geomorphic Province, a 900-mile-long northwest-southeast trending structural block with similarly trending faults that extends from the Transverse Ranges in the north to the tip of Baja California in the south and includes the Los Angeles Basin. The Los Angeles Basin is relatively flat, except for a series of aligned, northwesterly trending, low-elevation hills and mesas called the Newport-Inglewood Structural Zone, which divides the basin into subbasins or plains—the Torrance Plain on the west and the Downey and Tustin Plains on the east. The Project corridor is located in the Tustin Plain, which is relatively flat and slopes gently southwesterly toward the coast. The basin floor rises

to as much as 100 feet 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 site lies west of the Santa Ana Mountains, within alluvial fan complexes. According to geological maps of the Santa Ana/San Bernardino and Long Beach quadrangles, the California Geological Survey Geologic Data Map No. 2, and the Log-of-Test-Borings (LOTB) sample, the Project Area is underlain by Quaternary-aged alluvial fan sediments (Qyf). The LOTBs show interlayered clay and silty sand with interspersed gravel lenses. Artificial fill soils associated with past improvements are also documented near the ground surface within nearby LOTBs. Interstate (I) 5 traverses a generally flat, developed area with no unique or unusual geologic features within or adjacent to the Project Area.

2.10.2.2 Geologic Hazards

Geological hazards relevant to the Project Area include seismic ground shaking, localized soil liquefaction, and seismic settlement. The following irrelevant geologic hazards are evaluated for the proposed Project corridor and are not discussed further in this section:

- **Tsunami and Seiches:** Seiches are large waves generated in enclosed bodies of water, 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 Area. As a result, the existing potential risks to the proposed Project corridor 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. In addition, the Project Area has shown to not be located within a zone that is susceptible to seismically induced landslides.
- **Rock Falls:** Geologic hazards such as landslides or falling rocks are typical in areas of steep slopes. The Project Area is generally flat with gentle slopes; therefore, falling rocks are unlikely to occur in the Project Area.
- **Soil Subsidence:** Soil subsidence occurs when large amounts of groundwater have been withdrawn from certain types or rocks, such as fine-grained sediments.

When water is withdrawn, the rock falls in on itself and over large areas can result in occurrences such as sinkholes (USGS 2018). In general, none of the affected Project Area cities call out areas within their respective jurisdictions' General Plans that are specifically subject to soil subsidence. Therefore, soil subsidence is unlikely to occur in the Project Area.

- **Non-Seismically Induced Earth Movement:** Non-seismically induced earth movement can refer to sources such as debris flows, dam collapses, and occurrences such as avalanches, which could cause unstable geologic formations without registering any seismic activity. In general, unstable geologic formations occur outside of the Project Area within each of the affected Project Area cities. 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 California Geological Survey Map of Aggregate Sustainability in California[1] does 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 3.33 miles from the I-5 Project segment; as a result, moderate-to-intense ground shaking should be anticipated within the proposed Project corridor in the event of an earthquake. Faulting and seismicity are discussed in more detail below.

Some near-surface alluvial sediments within the Project Area are susceptible to liquefaction due to moderate-to-intense ground shaking and historical groundwater levels ranging from 4141 to 9494 feet 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. 2018. Website: https://www.conservation.ca.gov/cgs/Documents/Publications/Map-Sheets/MS_052_California_Aggregates_Report_201807.pdf (accessed March 1, 2023).

Faulting and Seismicity

The Project Area 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 intersecting the proposed Project corridor, and no Alquist-Priolo Earthquake Fault Zones have been identified in the Project Area. Nearby active or potentially active surface faults include the El Modeno Fault, the Peralta Hills Fault, the Whittier Fault, the Newport-Inglewood Fault, the Pelican Hill Fault, and the San Joaquin Hills 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. The San Joaquin Hills Blind Thrust Fault is approximately 88.9 miles from the nearest portion of the proposed Project corridor and is considered to have low potential for surface rupture. The nearest mapped Quaternary fault is the El Modeno Fault. The El Modeno Fault is approximately 3.33 miles northeast of the nearest portion of the proposed Project corridor. The Whittier Fault extends northwesterly west along the eastern flank of the Santa Ana Mountains and is approximately 9.7 miles northeast of the nearest point along the proposed Project corridor. 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	Age	Approximate Distance from I-5/ Katella Avenue to Fault (miles)
El Modeno	R	Quaternary	3.3
Peralta Hills	R	Late Quaternary	4.4
Whittier	SS	Holocene	9.7
Los Alamitos	Uncertain	Late Quaternary	11
Newport Inglewood Fault Zone (South Los Angeles Basin Section-Southern)	SS	Holocene	11.4
Pelican Hill	SS	Late Quaternary	12.3
San Joaquin Hills	R	Late Quaternary	13.4

Source: *Fault Activity Map of California. California Department of Conservation,* https://maps.conservation.ca.gov/cgs/fam/ (2015)5
I = Interstate
R = Reverse
SS = Strike-Slip

The Project Area 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, along 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 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 that there are no unrecognized active faults at the site

Groundwater

The potential for liquefaction within the Project Area was determined based on groundwater levels near the ground surface. Groundwater depth fluctuates throughout the Project Area. Recent borings and as-built LOTBs show that groundwater at the northern end of the Project Area, between Coyote Creek Bridge (Post Mile [PM] LA-5-0.3) and Magnolia Avenue (PM ORA-5-41.93), occurs as shallow, perched groundwater. The groundwater depth increases around Brookhurst Avenue (PM ORA-5-40.7), where it remains at depths of 41.7 to 93.5 feet below native ground surface (Elevation 61.8 to 39.5). A summary of the maximum historical groundwater elevations from as a-built LOTBs is provided in Table 2.10.2, below.

Liquefaction Potential and Seismic Settlement

About half of the total Project Area is mapped by the California Geological Survey as being in a zone that is susceptible to earthquake-induced liquefaction. Liquefaction is a phenomenon whereby saturated granular soils lose their inherent shear strength due to increased pore water pressures, which may be induced by conditions such as an earthquake. Liquefaction is generally considered possible when the depth to groundwater is less than 50 feet below the ground surface. As shown in Table 2.10.2, above, historical high groundwater levels in the Project Area are between 19 and 95 feet below ground surface along the I-5 Project segment. Groundwater may vary locally, with potential for shallow conditions along major streams and tributaries. Depending on locally specific conditions, liquefaction has the potential to affect the proposed Project Area.

Table 2.10.2: Summary of Groundwater Data

Location	Surface Elevation (feet)	Depth to Groundwater (feet)	Groundwater Elevation (feet)	Date Measured	Bridge No.	Boring No.
Coyote Creek Bridge	65.3[3]	19.3[3]	48.3[3]	10/5/65	53-0298	B-1
Stanton Ave. OC	80[3]	19.3[2,3], 37.3[2,3]	63[2,3], 44[2,3]	3/31/54	55-0211	B-4
Fullerton Creek Bridge	80.9	18	62.9	4/10/97	55-0087R	B-1
Magnolia Ave.	93	32.2	60.8	11/28/95	55-0613	B-4
Brookhurst St.	119.3[3]	64[3]	57.6[3]	4/17/73	55-0024L	B-5
Euclid St. SB Off-Ramp	128.6	80.1	48.5	2/16/95	55-0843	B-1
Retaining Wall No. 192	140.3	NE[1]	NE[1]	1/31/97	55-0986M	B-4
Katella Ave. UC	141.8	83.1	58.7	10/3/94	55-0820	B-1
Gene Autry Wy.	137.5	85	52.5	3/26/03	55-0818L	A-03-001
La Veta Ave. OC	132.3[3]	NE[1]	NE[1]	2/20/90	55-0677	BA-2B
La Veta Ave. OC	138.3[3]	92.3[3]	48.3[3]	3/7/90	55-0677	BA-3
La Veta Ave. OC	138.3[3]	94.3[3]	46.3[3]	3/8/90	55-0677	RW-6
South Connector OC	135.3[3]	95.8[3]	41.8[3]	3/5/90	55-0679G	RW-8
17th St. UC	168.3[3]	NE[1]	NE[1]	5/2/89	55-0673R/L	B-122
17th St. UC	148.3[3]	NE[1]	NE[1]	3/27/89	55-0673R/L	B-48
20th St. OC	150.8[3]	NE[1]	NE[1]	4/3/89	55-0676	B-58
20th St. OC	152.6[3]	NE[1]	NE[1]	4/24/89	55-0676	B-123
Grand Ave. UC	149.3[3]	NE[1]	NE[1]	3/31/89	55-0671L	B-17
1st St. Off-Ramp OC	140.2[3]	89.1[3]	53.4[3]	9/2/88	55-6615	B-1
SB Off-Ramp OC	122.8[3]	68.3[3]	56.8[3]	3/4/90	55-0642K	B-3
Newport Ave. UC	117[3]	NE[1]	NE[1]	6/10/88	55-0192	B-1
Red Hill Ave. UC	105.8[3]	44[3]	64.1[3]	6/7/88	55-0193	B-2

[1] = Not Encountered
[2] = Perched Groundwater
[3] = Converted from National Geodetic Vertical Datum of 1929 (NGVD29)
OC = Overcrossing
SB = Southbound
UC = Undercrossing

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 I-5 within the Project Area has been used during periods when leaded gasoline was still in use, the adjacent unpaved surficial soils may contain ADL. 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 Alternatives (Alternatives 2, 3, and 4)

The potential temporary impacts of the Build Alternatives related to geotechnical hazards and resources would vary depending on the alternative. Alternative 4 would require the most construction, due to the addition of a new Express Lane (EL) on I-5 in each direction between State Route (SR) 57 and SR-91, whereas Alternative 3 would require less than Alternative 4 but more than Alternative 2. Alternative 2 would require the least amount of construction since it includes only construction of the two park-and-ride facilities and some minor improvements to I-5 within the Project Area. Temporary impacts of the Build Alternatives are discussed generally in this section.

Soil Erosion

During construction, Alternative 2 would disturb a total of 2.60 acres of surface area. Construction activities for the sign replacement and development of the park-and-ride facilities would include clearing and grubbing; grading; and excavation. Soil would be exposed and there would be a potential for soil erosion compared to existing conditions. Soil eroded from the land which may include pesticides and other chemicals, has the potential to wash into streams and waterways. Additionally, during a storm event, soil erosion could occur at an accelerated rate. Alternative 3 would disturb a total area of 9.03 acres.

During construction, Alternative 3 would disturb a total area of 9.03 acres. Alternative 3 would result in similar impacts to water quality from soil erosion as those discussed above for Alternative 2 because both Build Alternatives include similar construction activities such as clearing and grubbing, grading, excavation, paving and sealing. Under Alternative 3, erosion is also a concern given the movement of soils during excavation and grading activities for the proposed soundwall.

During construction, Alternative 4 would disturb a total of 24.61 acres of surface area. Alternative 4 would result in similar impacts to water quality as those discussed above for Alternative 3.

During all construction activities for the Build Alternatives, the construction contractor would be required to adhere to the requirements of the General Construction Permit and to implement soil 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 Stormwater 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 Alternatives 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, ramps, and arterial streets within the Project Area 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 Alternatives and the Project Features (PFs) addressing those potential effects.

No Build Alternative (Alternative 1)

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

2.10.3.2 Permanent Impacts

Build Alternatives (Alternatives 2, 3, and 4)

The potential permanent impacts of the Build Alternatives related to geotechnical issues and resources along the proposed Project corridor would vary depending on the alternative. Alternative 4 would require the most construction, due to the addition of a new EL on I-5 in each direction between SR-57 and SR-91, whereas Alternative 3 would require less than Alternative 4 but more than Alternative 2. Alternative 2

would require the least amount of construction since it includes only construction of the two park-and-ride facilities and some minor improvements to I-5 within the Project Area. Permanent impacts are discussed generally in this section.

Local Geology, Topography, and Soils

The Build Alternatives 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 and would be designed to conform to current design standards. Surficial soils within the Project Area contain some amount of cohesive fines. Cohesive soils have an attraction between particles of the same type, origin, and nature. Therefore, cohesive soils are a type of soil that stick to each other. Examples of cohesive soils are the silts and clays, or fine-grained soils (Jackson 2020). Therefore, the soils are not easily eroded. However, slope areas that may consist of sandy surficial soils (with little to no cohesive fines) are susceptible to erosion. In general, the erosion potential of soils within the Project Area is considered low to moderate.

However, in the event of an earthquake, surface settlement could occur, which could damage the proposed roadway and compromise the integrity of proposed embankments, ramps, retaining walls, and other structures. As identified in Project Feature PF-GEO-1, soils and groundwater conditions along the proposed Project corridor would be evaluated through a site-specific investigation as part of the engineering design of the Build Alternatives. The results of this investigation would inform the final engineering design of the Build Alternatives. Design and construction of the proposed improvements would adhere to the Caltrans *Highway Design Manual* (HDM) and other required standards, as well as recommendations from the Structure Foundation Report and the Geotechnical Design Report, as included in minimization measure GEO-1 under section 2.10.4 below.

Adherence to recommendations within the Structure Foundation Report and Geotechnical Design Report would substantially reduce the geologic risks. 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. The revegetation of graded slopes specified in Project Feature PF-GEO-1 would be performed prior to construction of the Build Alternatives, which would address soil erodibility.

PF-GEO-1 **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, Project Feature PF-WQ-2 from Section 2.9.3 would also apply, as it requires the Project to implement Construction Best Management Practices (BMPs) which would require erosion control for slope stabilization.

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

The Project Area is located within the Los Angeles Basin, which is known to be seismically active. Depending on site-specific conditions, the Build Alternatives have the potential to also be underlain by liquefiable soil, thus potentially exposing the traveling public to hazards such as earthquakes and liquefaction. In the event of an earthquake, such conditions could result in surface settlement that could damage the proposed roadway and compromise the integrity of proposed embankments, ramps, retaining walls, and other structures. These conditions would be determined through a geotechnical investigation as part of the Project's engineering design (refer to measure GEO-1, above) to confirm soil and groundwater conditions along the Project alignment.

Based on the preliminary plans, the majority of fill placement for embankment construction is expected to be minor (5 feet 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. Construction of the improvements under Alternative 2 would result in ground disturbance of up to 5 feet. Construction of the improvements under Alternatives 3 and 4 would result in ground disturbance of up to 25 feet. With implementation of measure GEO-1, Alternatives 3 and 4 would be designed to conform to Caltrans' seismic and design criteria.

No Build Alternative (Alternative 1)

Under the No Build Alternative, the permanent impacts discussed above for the Build Alternatives would not occur because none of the permanent improvements to I-5 proposed under the Build Alternatives would be implemented and operated.

2.10.4 Avoidance, Minimization, and/or Mitigation Measures

The Build Alternatives will incorporate Project Feature PF-GEO-1 outlined in Section 2.10.3.2 to help address potential impacts. In addition, the Build Alternatives will include measure GEO-1 to properly assess and minimize potential impacts to geotechnical sites as part of the Build Alternatives.

GEO-1 **Geotechnical Investigation.** Under this measure 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 Alternatives.

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