3.7 GEOLOGY AND SOILS

This section of the 2024 PEIR describes the geological characteristics of the SCAG region, sets forth the regulatory framework that governs geology and soils, and analyzes the significance of the potential impacts that could result from implementation of Connect SoCal 2024. In addition, this 2024 PEIR provides regional-scale mitigation measures as well as project-level mitigation measures that can and should be considered and implemented by lead agencies for subsequent, site-specific environmental review to reduce identified impacts as appropriate and feasible. Impacts related to erosion and sedimentation as relates to water quality are discussed in further detail in Section 3.10, *Hydrology and Water Quality*, of this 2024 PEIR, while impacts associated with the loss of topsoil as relates to agricultural resources are addressed in Section 3.2, *Agriculture and Forestry Resources*. Impacts to archaeological/historic resources and tribal cultural resources are discussed in Section 3.5, *Cultural Resources*, and Section 3.18, *Tribal Cultural Resources*, respectively, of this 2024 PEIR.

3.7.1 ENVIRONMENTAL SETTING

DEFINITIONS

Definitions of terms used in the regulatory framework, characterization of baseline conditions, and impact analysis for geology and soils follow:

- *Alluvium:* An unconsolidated accumulation of stream deposited sediments, including sands, silts, clays, or gravels.
- *Extrusive igneous rocks:* Rocks that crystallize from molten magma on earth's surface.
- *Fault:* A fracture or fracture zone in rock along which movement has occurred.
- *Formation:* A laterally continuous rock unit with a distinctive set of characteristics that make it possible to recognize and map from one outcrop or well to another. The basic rock unit of stratigraphy.
- *Holocene:* An interval of time relating to, or denoting the present epoch, which is the second epoch in the Quaternary period. The California Geological Survey (CGS) defines the Holocene as from approximately 11,700 years ago to the present time; the U.S. Geological Survey (USGS) uses 15,000 years ago.
- *Liquefaction:* The process by which water-saturated sandy soil materials lose strength and become susceptible to failure during strong ground shaking in an earthquake. The shaking causes the pore-water pressure in the soil to increase, thus transforming the soil from a stable solid to a more liquid form.
- *Modified Mercalli Intensity (MMI) Scale:* The MMI scale assigns an intensity value based on the observed effects of ground shaking produced by an earthquake. Unlike measures of earthquake magnitude and peak ground acceleration (PGA), the Modified Mercalli Intensity Scale is qualitative in nature in that it is based on actual observed effects rather than measured values. Similar to PGA, Modified Mercalli values for an earthquake at any one place can vary depending on the earthquake's magnitude, the distance from its epicenter, the focus of its energy, and the type of geologic material. The Modified Mercalli values for intensity range from I (earthquake not felt) to XII (damage nearly total), and intensities ranging from IV to X can cause moderate to significant structural damage. Because the Modified Mercalli scale is a measure of ground shaking effects, intensity values can be correlated to a range of average PGA values.
- *Moment magnitude (Mw):* Also called moment magnitude scale, quantitative measure of an earthquake's magnitude (or relative size) using a logarithmic scale. Calculations of an earthquake's size using the moment magnitude scale are tied to an earthquake's seismic moment rather than to the amplitudes of seismic waves

recorded by seismographs. The moment magnitude scale is the only scale capable of reliably measuring the magnitudes of the largest, most destructive earthquakes (that is, greater than magnitude 8). The first logarithmic scale was developed in the 1930s by Charles Richter and became known as the Richter scale. The Richter and other similar scales are valid for a particular frequency range and type of seismic signal. The Richter magnitude scale reflects the maximum amplitude of a particular type of seismic wave. Moment magnitude provides a physically meaningful measure of the size of a faulting event (CGS 2002). Richter magnitude estimations can be generally higher than moment magnitude estimations. The discussion of earthquake magnitudes in this 2024 PEIR all refer to moment magnitude.

- *Oligocene:* An interval of time relating to, or denoting the third epoch of the Tertiary period, between the Eocene and Miocene epochs, from approximately 34 to 23 million years ago.
- *Outcrop:* A rock formation that is visible on earth's surface.
- *Paleozoic:* An interval of time relating to, or denoting the era between, the Precambrian eon and the Mesozoic era, from approximately 541 to 252 million years ago.
- *Peak ground acceleration (PGA):* A common measure of ground motion at any particular site during an earthquake. The PGA is expressed as the percentage of the acceleration due to gravity (g), which is approximately 980 centimeters per second squared. Unlike measures of magnitude, which provide a single measure of earthquake energy, PGA varies from place to place and is dependent on the distance from the epicenter and the character of the underlying geology (e.g., hard bedrock, soft sediments, or artificial fills).
- *Pleistocene:* An interval of time relating to, or denoting the first epoch of the Quaternary period, between the Pliocene and Holocene epochs, from approximately 2.6 million years ago to 11,700 years ago.
- *Pliocene:* An interval of time relating to, or denoting the last epoch of the Tertiary period, between the Miocene and Pleistocene epochs, from approximately 5.5 to 2.6 million years ago.
- *Plutonic igneous rocks:* Igneous rocks that have crystallized beneath the earth's surface.
- *Pore water pressure:* Refers to the pressure of groundwater held within a soil or rock, in gaps between particles (pores).
- *Quaternary:* The most recent period in geological time; includes the Pleistocene and Holocene Epochs.
- *Soil association:* A mapping unit consisting of a group of defined and taxonomic soil units occurring together in an individual and characteristic pattern over a geographic region.
- *Unique geologic feature:* An important and irreplaceable geological formation. Such features may have scientific and/or cultural values.
- *Unique paleontological resource:* A fossil or the geological unit that contains the fossil that meets one or more of the following criteria:
  - It provides information on the evolutionary relationships and developmental trends among organisms, living or extinct.
  - It provides data useful in determining the age(s) of the rock unit or sedimentary stratum, including data important in determining the depositional history of the region and the timing of geologic events therein.
  - It provides data regarding the development of biological communities or interaction between plant and animal communities.
  - It demonstrates unusual or spectacular circumstances in the history of life.

- The fossils are in short supply and/or in danger of being depleted or destroyed by the elements, vandalism, or commercial exploitation, and are not found in other geographic locations.

REGIONAL GEOLOGIC CONDITIONS

The SCAG region extends primarily over four California geomorphic provinces: the Transverse Ranges, the Peninsular Ranges, the Colorado Desert, and the Mojave Desert (**Map 3.7-1, Geomorphic Provinces**).[1] The stratigraphic units of southwestern California, including those of the SCAG area, are separated into two large groups by a pronounced unconformity[2] of mid-Cretaceous age (about 100 million years ago). Below the unconformity are basement rocks composed of metamorphic and igneous crystalline rocks of Precambrian (before 540 million years ago) to early Late Cretaceous age. Above the unconformity is a thick succession of marine and non-marine sedimentary and volcanic rocks of Late Cretaceous to Recent age (Yerkes et al. 1965). These provinces are naturally defined geologic regions that display distinct landscape or landform and geology, as summarized below.

TRANSVERSE RANGES

The Transverse Ranges are an east–west trending series of steep mountain ranges and broad alluvial valleys that extends approximately 320 miles from Point Arguello in the west to the Little San Bernardino Mountains in the east. The east–west structure of the Transverse Ranges is oblique to the normal northwest trend of coastal California, hence the name “Transverse.” This geomorphic province includes Ventura County and portions of Los Angeles, San Bernardino, and Riverside Counties. It also extends offshore to include San Miguel, Santa Rosa, and Santa Cruz islands.

There is intense north–south compression squeezing the Transverse Ranges and resulting in the prominent basins and ranges found in this province, including the Ventura Basin and the San Gabriel and San Bernardino Mountains. This is one of the most rapidly rising regions on earth. Several active faults, such as the San Andreas Fault Zone, are located in the Transverse Ranges. Other faults in the province include the Santa Clara River Valley Fault, the San Gabriel Fault Zone, the Santa Cruz Island Faults, the Santa Rosa Island Faults, and the Soledad Faults. This province is one of the most geologically diverse in California, containing a wide variety of bedrock types and structures. California’s highest peaks south of the central Sierra Nevada and the only Paleozoic rocks in the coastal mountains in the United States are found here. Because of the great lithological diversity, the province is further subdivided into eight subprovinces, each displaying its own geologic signature. Broad illuviated valleys, narrow stream canyons, and prominent faults separate these subprovinces.

PENINSULAR RANGES

The Peninsular Ranges province consists of a series of ranges separated by northwest trending valleys, subparallel to faults branching from the San Andreas Fault Zone. This province is bounded on the northwest by the Transverse Ranges, on the east by the Colorado Desert, and extends south, encompassing the Los Angeles Basin and terminating 775 miles south of the United States–Mexico border.

The Peninsular Ranges includes the southern portion of Los Angeles County, the southwest corner of San Bernardino County, all of Orange County, and the San Jacinto Mountains and the Coachella Valley in the central

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1 A small sliver of the northwest corner of San Bernardino County is located in the Basin and Range province, and a small area in northern Ventura County is located in the Southern Coastal Ranges province.

2 An unconformity is a buried erosional or non-depositional surface separating two rock masses or strata of different ages, indicating that sediment deposition was not continuous.

portion of Riverside County. The ranges are composed of a series of northwest-southeast trending mountains that are separated by several active faults, including the San Jacinto and Elsinore Fault Zones. The bedrock of the Peninsular Ranges contains a record of the initiation of the subduction zone that dominated the Mesozoic. The older deep marine deposits have been metamorphosed to varying degrees by Cretaceous intrusions. These intrusions, or batholith, form the resistant backbone of the ranges. Younger marine and terrestrial sediments flank off the margins due to the later uplift. The Peninsular Ranges is one of the largest geologic units in western North America. Its highest elevations are found in the San Jacinto-Santa Rosa Mountains, with San Jacinto Peak reaching 10,805 feet above mean sea level (MSL). The orientation and shape of the Peninsular Ranges is similar to the Sierra Nevada, in that the west slope is gradual and the eastern face is steep and abrupt. Drainage from the province is typically by the San Diego, San Dieguito, San Luis Rey, and Santa Margarita Rivers.

Colorado Desert (Salton Trough)

The Colorado Desert geomorphic province (also referred to as the Salton Trough) is a depressed block between active branches of alluvium-covered San Andreas Fault with the southern extension of the Mojave Desert province in the east. Its roughly triangular shape is bounded to the east by the Chocolate Mountains, to the west by the Peninsular Ranges, and extends south into Mexico. The area is a low-lying, barren desert basin dominated by the Salton Sea. This province includes a large portion of Imperial County and a small portion of central Riverside County. The Colorado Desert is divided into two main valleys: the deep Imperial Valley to the south and the narrower and shallower Coachella Valley to the north. A good portion of both valleys lie below sea level with the lowest elevation found in the Salton Basin at 235 feet below MSL. The area is characterized by the ancient beach lines and silt deposits of extinct Lake Cahuilla. Geologic features include playas separated by sand dunes and the occurrence of seismic and a seismic subsidence due to the San Andreas Fault system.

Mojave Desert

The Mojave Desert geomorphic province occupies approximately 25,000 square miles. It is a broad interior region of isolated mountain ranges separated by expanses of desert. There are two important fault trends that control topography, a prominent northwest-southeast trend and a secondary east–west trend. The Mojave province is wedged in a sharp angle between the left-lateral Garlock Fault to the north (southern boundary Sierra Nevada) and the right-lateral San Andreas Fault to the west (where it bends east from its northwest trend). The Nevada state line roughly coincides with its eastern boundary, and the San Bernardino/Riverside County line defines its southern boundary. Portions of Los Angeles and San Bernardino Counties lie within this province.

The mountain ranges in the Mojave contain a record of complex and varied geological histories going back several billion years. The oldest rocks are crystalline basement that may or may not be related to similar aged rocks in Wyoming. From about 1 billion years to 250 million years ago, the Mojave recorded passive shallow to deep ocean deposition. By the Jurassic, about 160 million years ago, the area fully shifted to recording a subduction zone with volcanism, plutonism, and rifting. As the Mesozoic gave way to the Cenozoic, the region shifted to terrestrial sedimentation, filling in faulted basins. This early part of the history is recorded in the bedrock of the mountains.

Erosional features such as broad alluvial basins that receive non-marine sediments from the adjacent uplands dominate the Mojave Desert region. Numerous playas, or ephemeral lakebeds within internal drainage basins, also characterize the region. Throughout this province, small hills—some the remnants of ancient mountainous topography—rise above the valleys that are surrounded by younger alluvial sediments. The highest elevation approaches 4,000 feet above MSL, and most valleys lie between 2,000 to 4,000 feet above MSL.

Southern Coastline Geomorphic Sub-Province

Recently, the CGS has considered the coastline itself as a distinct geomorphic sub-province evenly divided between north and south (CGS 2015). The California coastline is another dynamic boundary zone, of varying width, where geologic forces collide. Coastal landforms include beaches, dunes, tide pools, estuaries, lagoons, steep cliffs, marine terraces, and sea stacks. Portions of the coast have been uplifted due to tectonic forces, while others have subsided. The interplay of uplift and sea level fluctuations produced numerous marine terraces all along the coast. The highest terraces can extend several miles inland to what was once the shoreline. Subsidence along with sea level rise since the end of the last Ice Age has drowned river mouths. This moved the shoreline inland. Such a dynamic setting has produced a long list of landscapes and features including accreted terranes, marine terraces, islands, sea stacks, dunes, beaches, and concretions.

The coastline can be subdivided into two sections. The northern section runs the length of the Coast Ranges province; the southern runs along the western edge of the provinces of the Transverse Ranges and the Peninsular Ranges. Along the southern section, the coastal geomorphology is superimposed on the landforms of the Transverse Ranges and Peninsular Ranges geomorphic provinces. The southern coastline trends northwestwardly from San Diego to Point Conception. Due to the orientation, the southern shores are somewhat sheltered from storms that arrive from the west and northwest. A broad continental shelf lies along the southern section. The shallow offshore shelf helps absorb wave energy by causing waves to break further from shore. Sand deposition started roughly 10,000 years ago and is relatively widespread along the southern coast, creating the state's popular beaches.

The position of the shoreline is directly related to sea level and land elevation, both of which are variable through time. Sea level was as much as 400 feet lower during the last Ice Age because so much water was trapped as ice on the glaciers that covered northern and southern latitudes. During this time the shoreline position was as much as several miles west of its current location extending toward the Channel Islands. During the Ice Ages, major rivers cut deep canyons into the continental shelf, creating submarine canyons. During the last interglacial, sea level was approximately 15 to 20 feet higher and coastal wetlands and estuaries were correspondingly much more extensive than they are today.

Faults and Seismicity

The SCAG region is seismically active. In the past 100 years, several earthquakes of magnitude 5.0 or larger have been reported on the active San Andreas, San Jacinto, Elsinore, and Newport-Inglewood fault systems. These four fault systems are concentrated in the western portion of the SCAG region, running in a northwest to southeast direction. The San Andreas Fault lies furthest to the east, extending just above the northern border of Ventura County and the San Gabriel Mountains and southward to the Salton Sea. As a result, significant earthquake hazards exist in the region.[3] Injury to people and damage to structures during earthquakes can be caused by actual surface rupture along an active fault, by ground shaking from a nearby or distant fault, or seismic-induced ground failures (e.g., liquefaction, lateral spreading, or landslides). In Southern California, the largest historic earthquake was the magnitude 7.9 Fort Tejon earthquake that occurred in 1857 (USGS 2019b). Much more frequent are smaller temblors, like the relatively moderate (but still exceedingly damaging) 1971 San Fernando and 1994 Northridge

3 It should be noted that new faults continue to reveal themselves, such as in the case of the Ridgecrest quake of 2019, and the potential seismic threats posed by these faults also continue to be reevaluated based on new geologic information and analysis.

earthquakes, both classified as magnitude 6.7 earthquakes.[4] In July 2019, a magnitude 7.1 earthquake struck on a previously unnamed fault system near Ridgecrest in San Bernardino County. Two foreshocks of 5.4 and 6.1 preceded the larger 7.1 earthquake.

A fault is a fracture in the crust of the earth along which there has been displacement of the sides relative to one another parallel to the fracture. Most faults are the result of repeated displacements over a long period of time. Numerous active and potentially active faults have been mapped in the region (**Table 3.7-1, Characteristics of Major Faults in the SCAG Region**, and **Map 3.7-2, Alquist-Priolo Earthquake Fault Zones and Areas of Probabilistic Ground Acceleration**) (USGS 2023b; CGS 2016). The SCAG region contains lateral strike-slip faults[5] (e.g., the San Andreas Fault Zone) and various identified and hidden blind thrust faults.[6] A fault trace is the surface expression of a particular fault. Buried or blind thrust faults are thought to underlie much of the SCAG region. These "buried" faults do not exhibit readily identifiable traces on the earth's surface and are typically at considerable depth within the underlying geologic formation. Although these faults typically do not offset surface deposits, they can generate substantial ground shaking. The CGS defines active faults as those that have exhibited evidence of displacement during the Holocene (11,700 years ago to present) period.[7] Potentially active faults are defined as faults that have exhibited evidence of displacement during the Pleistocene period (11,700 years to 2.6 million years ago). Class A faults have geologic evidence that demonstrates the existence of a Quaternary fault of tectonic origin, whether the fault is exposed for mapping or inferred from liquefaction or other deformational features. Class B faults have geologic evidence that demonstrates the existence of a fault or suggests Quaternary deformation, but either (1) the fault might not extend deeply enough to be a potential source of significant earthquakes, or (2) the currently available geologic evidence is too strong to confidently assign the feature to Class C but not strong enough to assign it to Class A. Class C faults have geologic evidence that is insufficient to demonstrate (1) the existence of tectonic fault or (2) Quaternary slip or deformation associated with the feature.

TABLE 3.7-1 **Characteristics of Major Faults in the SCAG Region**

Fault	Counties	Recency	Slip-Rate (mm/yr)	Max. Moment
Class A Faults				
San Andreas	Los Angeles San Bernardino Riverside Imperial	Historic Late Quaternary Latest Quaternary	24.0–34.0	7.2–7.5

4 The human and economic damage caused by earthquakes tends to increase with time, as more and more people and property come to occupy more and more of the land, thus cumulatively increasing the exposure of human habitation to seismic hazard. The 1994 Northridge earthquake, though hardly the most severe experienced by Southern California, was deemed the most expensive, in terms of its economic cost and its damage to human property. The California Office of Emergency Services claimed a $15 billion total damage estimate.

5 For strike-slip faults, the fault plane is essentially or close to vertical, and the relative slip is lateral along the fault plane. Strike-slip faults are right lateral or left lateral, depending on whether the block on the opposite side of the fault from an observer has moved to the right or left.

6 A thrust fault is a type of reverse fault (i.e., a dip-slip fault where the hanging wall moves upwards relative to the footwall) that has a fault plane dip of 45 degrees or less. If the fault plane terminates before it reaches the Earth's surface, it is referred to as a blind thrust fault.

7 The U.S. Geological Survey (USGS) uses 15,000 years ago to present.

FAULT	COUNTIES	RECENCY	SLIP-RATE (MM/YR)	MAX. MOMENT
San Jacinto–Imperial Fault Zone	San Bernardino Riverside Imperial	Historic Holocene Late Quaternary Latest Quaternary	4.0–20.0	6.6–7.2
Elsinore Fault Zone	Los Angeles Orange Riverside Imperial San Bernardino	Historic Holocene Late Quaternary Latest Quaternary	2.5–5.0	6.8–7.1
CLASS B FAULTS				
Elsinore and San Jacinto Fault Zones (Non A Faults)				
Brawley Seismic Zone	Imperial	Historic	25.0	6.4
Chino	San Bernardino Riverside	Latest Quaternary	1.0	6.7
Elmore Ranch	Imperial		1.0	6.6
Garlock Fault Zones				
Garlock – west	Los Angeles San Bernardino	Latest Quaternary	6.0	7.3
Garlock – east	San Bernardino	Late Quaternary Latest Quaternary	7.0	7.5
Owl Lake	San Bernardino	Latest Quaternary	2.0	6.5
Transverse – Ranges and Los Angeles Basin				
Clamshell-Sawpit	Los Angeles		0.5	6.5
Cucamonga	San Bernardino		5.0	6.9
Hollywood	Los Angeles	Late Quaternary Latest Quaternary	1.0	6.4
Holser	Los Angeles Ventura	Late Quaternary	0.4	6.5
Malibu Coast	Los Angeles Ventura	Late Quaternary Latest Quaternary	0.3	6.7
Mission Ridge – Arroyo Parida – Santa Ana	Ventura	Late Quaternary Latest Quaternary	0.4	7.2
Newport-Inglewood	Los Angeles Orange	Historic Late Quaternary Latest Quaternary	1.0	7.1
Oak Ridge	Ventura	Holocene Late Quaternary Latest Quaternary	4.0	7.0
Palos Verdes	Los Angeles	Late Quaternary Latest Quaternary	3.0	7.3

FAULT	COUNTIES	RECENCY	SLIP-RATE (MM/YR)	MAX. MOMENT
Raymond	Los Angeles	Late Quaternary Latest Quaternary	1.5	6.5
Red Mountain	Ventura	Late Quaternary Latest Quaternary	2.0	7.0
San Cayetano	Ventura	Late Quaternary Latest Quaternary	6.0	7.0
San Gabriel	Ventura Los Angeles San Bernardino	Holocene Late Quaternary Latest Quaternary	1.0	7.2
San Jose	Los Angeles	Late Quaternary	0.5	6.4
Santa Monica	Los Angeles	Late Quaternary Latest Quaternary	1.0	6.6
Santa Ynez (East)	Ventura	Late Quaternary	2.0	7.1
Santa Susana	Ventura Los Angeles	Historic Late Quaternary	5.0	6.7
Sierra Madre	Ventura Los Angeles San Bernardino	Holocene Historic Late Quaternary Latest Quaternary	2.0	7.2
Simi-Santa Rosa	Ventura Los Angeles	Late Quaternary Latest Quaternary	1.0	7.0
Ventura-Pitas Point	Ventura	Latest Quaternary	1.0	7.0
Verdugo	Los Angeles	Late Quaternary Latest Quaternary	0.5	6.9
Los Angeles Blind Thrusts				
Upper Elysian Park	Los Angeles	Quaternary	1.3	6.4
Northridge	Ventura Los Angeles	Historic	1.5	7.0
Puente Hills blind thrust	Los Angeles Orange	Historic Quaternary	0.7	7.1
San Joaquin Hills	Orange	Latest Quaternary	0.5	6.6
Transverse – Ranges and Mojave				
Blackwater	San Bernardino	Latest Quaternary Undifferentiated Quaternary	0.6	7.1
Burnt Mountain	San Bernardino Riverside	Historic Latest Quaternary	0.6	6.5
Calico-Hidalgo	San Bernardino	Historic Latest Quaternary Undifferentiated Quaternary	0.6	7.3

FAULT	COUNTIES	RECENCY	SLIP-RATE (MM/YR)	MAX. MOMENT
Cleghorn	San Bernardino	Late Quaternary Undifferentiated Quaternary	3.0	6.5
Eureka Peak	San Bernardino Riverside	Historic Latest Quaternary	0.6	6.4
Gravel Hills – Harper Lake	San Bernardino		0.6	7.1
Helendale – S. Lockhart	San Bernardino	Late Quaternary Latest Quaternary	0.6	7.3
Johnson Valley (Northern)	San Bernardino	Historic Latest Quaternary	0.6	6.7
Lenwood – Lockhart – Old Woman Springs	San Bernardino	Historic Late Quaternary Latest Quaternary	0.6	7.5
North Frontal Fault Zone (Western)	San Bernardino	Late Quaternary Latest Quaternary	1.0	7.2
North Frontal Fault Zone (Eastern)	San Bernardino	Latest Quaternary	0.5	6.7
Pinto Mountain	San Bernardino	Late Quaternary Latest Quaternary	2.5	7.2
Pisgah – Bullion Mountain – Mesquite Lake	San Bernardino	Historic Late Quaternary Latest Quaternary	0.6	7.3
S. Emerson – Copper Mountain	San Bernardino	Latest Quaternary	0.6	7.0

Sources: *Southern California Probabilistic Seismic Hazard Assessment Maps (PSHA) 2023*
USGS 2023b
CDMG and USGS 1996

Table Notes:

Recency of fault movement: Refers to the time period when the fault is believed to have last moved. The age is expressed in terms of the Geologic Time Scale. Generally, the older the activity on a fault, the less likely it is that the fault will produce an earthquake in the near future. For assessing earthquake hazard, usually only faults active in the Late Quaternary or more recently are considered. These include the following three non-overlapping time periods:

Historic: Refers to the period for which written records are available (approximately the past 150 years).

Latest Quaternary: Refers to a period of time between the present and 15,000 years before present. Faults of this age are commonly considered active.

Late Quaternary: Refers to the time period between the present and approximately 130,000 years before the present.

Where no recency data are given, no determination has been made.

The *Maximum Moment Magnitude* is an estimate of the size of a characteristic earthquake capable of occurring on a particular fault. Moment magnitude is related to the physical size of a fault rupture and movement across a fault.

SEISMIC HAZARDS

Movements on the previously identified faults would likely cause future earthquakes in the SCAG region. Earthquakes can originate in areas where potential seismic energy has built up along a fault over time but has not yet been released in the form of an earthquake. The Working Group on California Earthquake Probabilities (WGCEP), comprising USGS, CGS, and the Southern California Earthquake Center, evaluates the probability of one or more earthquakes of moment magnitude 6.7 or higher occurring in the state of California over the next 30 years (WGCEP 2015). It is estimated that the Southern California region has a 93 percent chance of experiencing an earthquake of 6.7 or higher over the next 30 years; among the various active faults in the region, the San Andreas, San Jacinto, and Elsinore Faults are the most likely to cause such an event.

The four major hazards generally associated with earthquakes are surface fault rupture (ground displacement), seismic ground shaking, and seismic-induced ground failures (e.g., liquefaction and lateral spreading, settlement, and landslides). A discussion of these types of seismic hazards is provided below.

Surface Fault Rupture

The surface expression of earthquake fault rupture typically occurs in the immediate vicinity of the originating fault. The magnitude and nature of the rupture may vary across different faults, or even along different segments of the same fault. Rupture of the surface during earthquake events is generally limited to the narrow strip of land immediately adjacent to the fault on which the event is occurring. Surface ruptures associated with the 1992 Landers earthquake in San Bernardino County extended for a length of 50 miles, with displacements varying from 1 inch to 20 feet (CGS 2022b).

The Seismic Hazards Mapping Act requires the State Geologist to establish regulatory zones (known as Earthquake Fault Zones) around the surface traces of active faults, and to issue appropriate maps (see Section 3.7.2, *Regulatory Framework*, for fault and seismic laws). Numerous active and potentially active earthquake faults are mapped throughout the SCAG region (Map 3.7-2). Detailed maps are distributed to all affected cities, counties, and state agencies for their use in planning new or renewed construction. Local agencies must regulate most development projects within the zones, including all land divisions and most structures intended for human habitation. Fault surface rupture almost always follows preexisting faults, which are zones of weakness. Rupture may occur suddenly during an earthquake, or slowly in the form of fault creep. Sudden displacements are more damaging to structures because they are accompanied by ground shaking. Fault creep is the slow rupture of the earth's crust. Not all earthquakes result in surface rupture (e.g., the 1994 Northridge Earthquake, Southern California Earthquake Data Center 2023). Potentially active faults have demonstrated movement within Pleistocene period (approximately 2.6 million years ago to 11,700 years ago). According to the California Division of Mines and Geology (CDMG), active and potentially active faults must be considered as potential sources of fault rupture (CDMG and USGS 1996).

Seismic Ground Shaking

Seismic ground shaking may affect areas hundreds of miles distant from the earthquake's epicenter. Historic earthquakes have caused strong ground shaking and damage in many areas of the SCAG region. The composition of underlying soils in areas located relatively distant from faults can intensify ground shaking. Areas that are underlain by bedrock tend to experience less ground shaking than those underlain by unconsolidated sediments such as artificial fill.

Earthquakes on the various and potentially active fault systems are expected to produce a wide range of ground shaking intensities in the SCAG region. The PGAs of 0.15g to 0.35g (corresponds to strong shaking on the MMI scale) and greater than 0.35 g (very strong to very violent on the MMI scale) are shown on Map 3.7-2. The estimated maximum moment magnitudes represent characteristic earthquakes on particular faults (Table 3.7-1). While the magnitude is a measure of the energy released in an earthquake, intensity is a measure of the ground shaking effects at a particular location. Shaking intensity and PGAs can vary depending on the overall magnitude, distance to the fault, focus of earthquake energy, and characteristics of geologic media. Generally, intensities are highest at the fault and decrease with distance from the fault.

Liquefaction and Lateral Spreading

Liquefaction is the rapid loss of shear strength experienced in saturated, predominantly granular soils below the groundwater level during strong earthquake ground shaking and occurs due to an increase in pore water pressure. Liquefaction-induced lateral spreading is defined as the finite, lateral displacement of gently sloping ground as a result of pore-pressure buildup or liquefaction in a shallow underlying deposit during an earthquake (Virginia Polytechnic Institute and State University [VT] 2013). The occurrence of this phenomenon is dependent on many complex factors, including the intensity and duration of ground shaking, particle-size distribution, and density of the soil.

The potential damaging effects of liquefaction include differential settlement, loss of ground support for foundations, ground cracking, heaving, and cracking of structure slabs due to sand boiling, and buckling of deep foundations due to ground settlement. Dynamic settlement (i.e., pronounced consolidation and settlement from ground shaking) may also occur in loose, dry sands above the water table, resulting in settlement of and possible damage to overlying structures. In general, a relatively high potential for liquefaction exists in loose, sandy soils that are within 50 feet of the ground surface and are saturated (below the groundwater table). Lateral spreading can move blocks of soil, placing strain on levees and roads that can lead to ground failure.

Liquefaction potential is a function of the potential level of ground shaking at a given location and depends on the geologic material at that location. Structural failure often occurs as sediments liquefy and cannot support structures that are built on them. Areas susceptible to liquefaction with the SCAG area are shown on **Map 3.7-3, Areas of Potential Liquefaction**. Alluvial valleys and coastal regions are particularly susceptible to liquefaction. These areas can include but are not limited to flood plains and former wetlands such as Marina Del Rey, Playa Del Rey, areas near the Los Angeles River, Santa Monica Bay and Alamitos Bay in Los Angeles County, areas in the vicinity the Santa Clara River, and Calleguas Creek outlets to the ocean in Ventura County. Additionally, there are areas in northern Los Angeles County that are susceptible to liquefaction as a result of existing geological conditions. Unconsolidated alluvial deposits in desert region deposits are rarely saturated because of the depth to the water table and are thus less susceptible to liquefaction than unconsolidated alluvium adjacent to stream channels.

Earthquake-Induced Settlement

Settlement or densification of the ground surface can be accelerated and accentuated by earthquakes. During an earthquake, settlement can occur as a result of the relatively rapid rearrangement, compaction, and settling of subsurface materials, particularly loose, uncompacted, and variable sandy sediments. Settlement can occur both uniformly and differentially (i.e., where adjoining areas settle at different rates). Areas are susceptible to differential settlement if underlain by compressible sediments. Densification typically occurs in old fills and in soils that, if saturated, would be susceptible to liquefaction.

Within the SCAG region, artificial fills, unconsolidated alluvial sediments, slope washes, and areas with improperly engineered construction-fills typically underlie areas susceptible to earthquake-induced settlement. The July 2019 M7.1 Ridgecrest Earthquake and its preceding foreshocks as large as M6.4 were felt across much of Southern California and into parts of Arizona, Nevada, and the San Francisco Bay Area (USGS 2019a). The M7.1 mainshock was the strongest earthquake to occur in the state in nearly 20 years. Although mobile homes, chimneys, and gas lines suffered damage, no major settlement or landslide incidents were reported as a result of this earthquake.

SEISMICALLY INDUCED LANDSLIDES

Strong ground shaking during earthquake events can generate landslides and slumps in uplands or coastal regions near the causative fault. Seismically induced land sliding has typically been found to occur within 75 miles of the epicenter of a magnitude 6.5 (or larger) earthquake. Seismically induced landslides would be most likely to occur in areas that have previously experienced landslides or slumps, in areas of steep slopes, or in saturated hillside areas. Portions of the SCAG region are susceptible to seismically induced land sliding because of the abundance of active faults in the region and the existing landslide hazards (**Map 3.7-4, Areas of Potential Landslides**). Specifically, areas with high susceptibility to earthquake-induced landslides are concentrated along mountain ranges in the SCAG region: Santa Ana Mountains, San Gabriel Mountains, Santa Susanna Mountains, Santa Monica Mountains, Sulphur Mountain, San Jacinto Mountains, and the San Bernardino Mountains.

SOILS AND GEOLOGIC MATERIALS

Soils within the SCAG region are classified by distinguishing characteristics and are arranged within soil associations. Soils throughout the region differ in origin, composition, and slope development. Individual soil characteristics are important in determining the suitability of the soil for agricultural use or urbanized development. The formation of surficial soil depends on the topography, climate, biology, local vegetation, and the material on which the soil profile is developed. Each soil type may have properties that could limit its uses and represent a development hazard. These limitations are listed and discussed below. **Map 3.7-5, General Soil Types**, shows the general location of soil types contained within the SCAG region (NRCS 2022).

EROSION

Erosion is the physical detachment and movement of soil materials through natural processes or human activities. Soil erosion is a natural ongoing process that erodes, transports, and displaces soil particles through a transport mechanism such as flowing water or wind. In addition, erosion results from man-made activity when soil coverings are stripped leaving the underlying soil exposed to the elements. The determination of soil erosion potential is a complex process generally applied to site specific areas using the soil erodibility K factor index (NRCS 2023). The K factor combines the detachability of soil, runoff potential of the soil, and transportability of the sediment eroded from the soil into one measure for soil erodibility. The K factor is just one element of the Revised Universal Soil Loss Equation (RUSLE), which is used by government agencies to make erosion predictions for regulatory and conservation planning uses.

Determining areas of potential erosion is made more complex due to the substantial geomorphic diversity in the SCAG region. Generally, there is a high potential for erosion in mountainous areas and areas along the margins of mountainous areas, where there is a high intensity of rainfall, the soils are considered erosive, and such soils are present on slopes. Clay soils typically have low erodibility because the soil particles are resistant to detachment. Soils having a high silt content are the most erosive as the particles are easily detached, tend to crust, and produce high rates of runoff.

SOIL

Three soil factors are strongly associated with soil erosion potential: texture, compactness, and structure. Of these, texture plays the most dominant role. Intermediate textured soil types, such as silt, tend to be most erodible, whereas clay and particles coarser than sand are more resistant to erosion. Slopes influence the rate and amount of runoff, and in turn influence erosion. Loose texture and steep slopes primarily result in high wind erosion potential in soils. Data on soil erodibility (K factor) indicate there are areas within the SCAG region with both moderate (K factor 0.25–0.45) and high susceptibility (K factor > 0.45) of erosion, as shown on **Map 3.7-6, Soils with Moderate to High Erosion Potential**. In Ventura County, most of the Santa Monica Mountains and Topatopa Mountains are characterized by soils that are moderately susceptible to erosion. In Los Angeles County, most soils within the urbanized areas south of the San Gabriel Mountains are moderately susceptible to erosion. These soils continue southeast into Orange County where almost all of the land area is covered by soils moderately susceptible to erosion. In San Bernardino County, the majority of soils have low susceptibility to erosion, however several pockets of moderately erodible soils exist throughout the county, particularly surrounding the Ivanpah and Piute Mountains and Lanfair and Ivanpah Valleys; one small area of highly erodible soil exists in the northeast corner of the county within the Mesquite Valley. Riverside County also features both moderately and highly susceptible erodible soils that are mainly concentrated in the western portion of the county immediately adjacent to the east and west of the Lakeview Mountains. Finally, Imperial County is covered by moderately erodible soils on its west side, surrounding the Salton Sea and extending south.

Erosion caused by wind is most severe in arid regions where sandy or loamy sediments are not covered by vegetation and exposed to severe wind conditions, such as the eastern portions of San Bernardino, Riverside, and Imperial Counties. Human intervention can accelerate the natural erosion process. For instance, typical consequences of development increase erosion potential due to the removal of vegetative cover and reduction of overall permeable area. These activities can lead to increased water runoff rates and concentrated flows that have greater potential to erode exposed soils. The effects of excessive erosion range from nuisance problems that require additional maintenance, such as increased siltation in storm drains, to instances of more severe damage where water courses are down-cut and gullies develop. These processes can eventually undermine adjacent structures or topography. Human activities that disturb soils in arid regions also increase wind erosion potential. Many of the desert areas in the SCAG region are susceptible to blowing sand, a severe form of wind erosion that damages property and accumulates soil on roadways. The majority of the soils in the SCAG region exhibit moderate to high erosion potential, which can be compounded by development.

COASTAL

Coastal erosion is a natural process that is typically the most visible during storm events. Beach sand is replenished by sediment loads in rivers and gentler waves after storm events or during summer months. Erosion rates of one inch per year are considered moderate. However, depending on the severity and duration of storm events and the degree of human intervention with natural coastline or riverine processes, coastal erosion can proceed at considerable rates, resulting in rapid visible coastline recession. In areas of extreme coastal erosion, such as the cities of Rancho Palos Verdes and Malibu, slopes have been undercut by waves during storm events, causing slope failure and resulting in property damage and risks to human health and safety. Within the SCAG region, the coastal portions of Los Angeles, Orange, and Ventura Counties are susceptible to wave erosion hazards.

The Pacific Ocean borders the Peninsular Ranges province and the Transverse Ranges Province on the west. Nearly all the sea cliffs along the coast display some sign of coastal erosion. Coastal retreat is attributable to various processes, including undercutting from wave action, weathering and erosion of rocks and cliffs, emergence of groundwater at the cliff face, rain-wash, and land sliding. Additionally, these naturally occurring forces can be assisted by human activity such as coastal road construction, channelization of surface water flows, or development on marine terraces.

Expansive Soils

Expansive soils possess a "shrink-swell" behavior. Shrink-swell is the cyclic change in volume (expansion and contraction) that occurs in fine-grained clay sediments from the process of wetting and drying. Structural damage may result over a long period of time, usually the result of inadequate soil and foundation engineering or the placement of structures directly on expansive soils. Typically, soils that exhibit expansive characteristics are those within five feet of the surface. The effects of expansive soils could damage foundations of aboveground structures, paved roads and streets, and concrete slabs. Expansion and contraction of soils, depending on the season and the amount of surface water infiltration, could exert enough pressure on structures to result in cracking, settlement, and uplift. Locations of expansive soils are site-specific and can generally be remedied through standard engineering practices.

Settlement

Loose, soft soil material comprised of sand, silt and clay, if not properly engineered, has the potential to settle after a building is placed on the surface. Settlement of the loose soils generally occurs slowly but over time can amount to more than most structures can tolerate. Building settlement could lead to structural damage such as cracked foundations and misaligned or cracked walls and windows. Settlement problems are site-specific and can generally be remedied through standard engineering applications.

Land Subsidence

Land subsidence is caused by a variety of agricultural, municipal, or mining practices that contribute to the loss of support materials within a geologic formation. Agricultural practices can cause oxidation and subsequent compaction and settlement of organic clay soils or hydro-compaction allowing land elevations to lower or sink. Agricultural and municipal practices can result in the overdraft of a groundwater aquifer thereby causing aquifer settlement. Groundwater overdraft occurs when groundwater pumping from a subsurface water-bearing zone (aquifer) exceeds the rate of aquifer replenishment. The extraction of mineral or oil resources can also result in subsidence from removal of supporting layers in the geologic formation. Substantial subsidence occurs in the SCAG region due to groundwater extraction and subsequent lowering of the groundwater surface, typically beneath a confining clay stratum. Land subsidence can also result from persistent and prolonged drought. Prolonged drought can also exacerbate the above causes of subsidence as in the case of groundwater extraction for agricultural purposes. As there is less surface water available, more groundwater is extracted, thus increasing the potential for subsidence (Borchers and Carpenter 2014).

The impact of subsidence could include lowering of the land surfaces, increased potential for flooding, potential disturbance or damage to transportation infrastructure, buried pipelines and associated structures, and damage to structures designed with minimal tolerance for settlement. Historic occurrences of land subsidence due to groundwater extraction are reported in the SCAG region within Antelope Valley, Coachella Valley, and the Mojave River Basin Area. With groundwater level declines as high as 300 feet in some areas, subsidence has caused permanent damage to many of these landscapes.

Landslides

Landslides are the rapid downslope movement of a mass of material that moves as a unit and carries with it all the loose material above bedrock. Landslides occur more frequently on steep slopes or after periods of heavy rain due to the additional weight of water and its lubricating qualities. The material in the slope and external processes such as climate, topography, slope geometry, and human activity can render a slope unstable and eventually initiate slope movements and failures. Changes in slope material such as improperly engineered fill slopes can alter water movement and lead to chemical and physical changes within the slope. Unfavorable fracture or joint orientation and density may develop as a rock material responds to reduced weight or strain relief, resulting in a decreased ability of the rock material to resist movement. Removing the lower portion (the toe) decreases or eliminates the support that opposes lateral motion in a slope. This can occur by man-made activity such as excavations for road-cuts located along a hillside. Oversteepening a slope by removing material can also reduce its lateral support. Placement of buildings on slopes can increase the amount of stress that is applied to a potential failure surface. Shaking during an earthquake may lead materials in a slope to lose some cohesion, cause liquefaction, or change pore water pressures. Landslide-susceptible areas within the SCAG region are those with low-strength soil material on hilly topography; for example, the Portuguese Bend and Point Fermin areas of the Palos Verdes Peninsula, and the Blackhawk slide area on the north slope of the San Bernardino Mountains. Factors that decrease resistance to movement in a slope include pore-water pressure, material changes, and structure. Areas susceptible to landslides are shown on Map 3.7-4.

SOILS CAPABLE OF SUPPORTING SEPTIC TANKS OR ALTERNATIVE WASTEWATER DISPOSAL SYSTEMS

The California State Water Resources Control Board has specific guidelines and requirements with regard to soil suitability for septic tanks and alternative wastewater disposal systems in their publication 3.2C-Construction Practices – Onsite Wastewater Treatment Systems (OWTS) (SWRCB 2018). Soils with poorly or excessively drained soils are generally not suitable for septic tanks or alternative wastewater disposal systems. Onsite wastewater disposal systems are required to incorporate native soil knowledge into system design to prevent groundwater contamination and ensure long-term performance. Most often, a percolation test is performed to assess the infiltration rate and soil texture, both of which determine the site suitability for a wastewater disposal system. Since site suitability is determined by conducting on-site testing; suitability in the SCAG region would be determined on a project-by-project basis according to all applicable local, regional, and state requirements.

PALEONTOLOGICAL SETTING

Paleontological resources are critical for understanding how our planet and its intrinsic ecosystems have changed over time. By studying the past, we not only develop a fuller picture of our history but also gain information to help guide models about future changes. The geological record preserved in the SCAG region showcases significant changes in the biosphere of Southern California.

The SCAG region covers many different geological units and depositional environments of the past several billion years. To best contextualize the paleontological resources, this section is focused on those geological formations within the SCAG region most likely to host significant fossils. Various agencies and professional societies define significance differently, but the commonality is to protect resources that are rare (such as vertebrate fossils), record unique conditions (such as Pleistocene playa lakes), or are in jeopardy of loss through looting or destructive activities. To best manage resources, the standard practice is to initially define the significance based on published, mappable geological formations. The higher the mapping resolution, the more accurate the evaluation. Specific projects can then be quickly assessed and, if necessary, be assigned higher-detail scrutiny.

For this section, the recommendations of the Society of Vertebrate Paleontology (SVP) are followed as they are the industry standard for non-federal projects. The SVP (2010) defines fossils as being over 5,000 years in age, while the U.S. Bureau of Land Management generally considers fossils to be Pleistocene in age or older (over 11,700 years in age; BLM 2016). Therefore, sediments younger than middle or early Holocene are too young to preserve fossil resources and have low paleontological sensitivity. Other types of geologic units with low sensitivity are moderately metamorphosed rocks, as the heat and pressure associated with metamorphism is likely to destroy fossils. High grade metamorphic rocks, as well as igneous rocks, have no paleontological sensitivity.

The discussion presented below groups formations by age and environment using the large-scale compilation geologic map of California (CGS 2010). Then, specific formations known for hosting significant paleontological resources are described in detail.

Cenozoic Marine Deposits

Cenozoic marine deposits date from the Paleocene to the Pliocene and were deposited on the ancient seafloor. These geologic formations are well known for being highly fossiliferous in southern California and may preserve a wide variety of marine fauna: invertebrates such as mollusks, crustaceans, echinoderms, and others; marine vertebrates such as shark and other fish, whales, seals, sea lions, and others; and even terrestrial vertebrates such as horse, camel, bison, and others that washed out to sea and where buried in the near-shore marine deposits.

These deposits are particularly common at the surface in the Transverse Ranges in Ventura County, where Eocene and Miocene units are prevalent, coastal Orange County, central Imperial County as scattered outcrops around the Salton Sea, and central Los Angeles County. In the subsurface, these deposits are likely to be encountered underlying the younger surficial alluvium across large parts of the Los Angeles and San Bernardino basins.

Some of these units with the highest paleontological sensitivity (SVP high potential) are discussed below:

- **Shallow Marine Deposits.** Shallow marine deposits such as the San Pedro Sand and the Palos Verdes Sand have a strong record of preserving Pleistocene-aged marine and terrestrial fossils. The San Pedro Sand has yielded a diverse fauna of nearshore marine invertebrates such as crabs, snails, bivalves, gastropods, and echinoids and vertebrates such as sharks, bony fish, amphibians, reptiles, birds, whales, antelopes, mammoth, dire wolves, rodents, and bison. These units are common along coastal southern California, including Ventura, Los Angeles, and Orange Counties in the SCAG region. Many abundant fossil localities have been collected from excavations in San Pedro around the Port of Los Angeles, where the setting is very similar to that of the program area, with artificial fill covering old marine deposits. These deposits have yielded thousands of specimens of marine invertebrates that are significant for reconstructing changes in shallow marine ecosystems as the climate has changed since the Pleistocene (SWCA 2019).
- **Fernando Formation.** The Fernando Formation dates to the Pliocene and consists of marine siltstone, sandstone, pebbly sandstone, and conglomerate. The Fernando formation is common in the Transverse Ranges, particularly in Los Angeles County, where it is found extensively in the subsurface throughout the Los Angeles Basin. The lower part of the Fernando Formation consists of a pebble-cobble conglomerate in a sandstone matrix that fines upwards (i.e., particles get smaller when moving upwards toward the surface) into a coarse sandstone and then a silty sandstone. The upper Fernando Formation consists of coarse-grained sandstone with conglomerate lenses. The Fernando Formation has an extensive record of preserving scientifically significant fossils, including invertebrates such as mollusks, echinoids, and bryozoans, fish, squid, and a number of unidentified megafossils (SWCA 2019). A collection search of the holdings of the University of California Museum of Paleontology (UCMP) returned over 50 invertebrate fossils from the Fernando Formation.
- **Bouse Formation.** The Bouse Formation spans the early Pliocene to the late Miocene and has been interpreted to represent either a marine estuarian or lacustrine depositional environment. The Bouse Formation is found in the Mojave Desert Geomorphic Province and consists of calcareous clay, silt, and sand.

Abundant common invertebrate fossils such as gastropods, ostracods, barnacles, and foraminifera, as well as fish and plants are known from the Bouse Formation (SWCA 2019).

- **Puente Formation.** The Puente Formation, often synonymous with the Modelo Formation, consists of marine sandstone, siltstone, and shale that dates from the early Pliocene to the Miocene. The Puente Formation has a history of preserving both invertebrate and vertebrate marine fossils, such as cephalopods, crustaceans, fishes, and other marine and terrestrial vertebrates (Santos et al. 2016). The Puente Formation is common in the Peninsular Ranges and Transverse Ranges provinces (SWCA 2019).
- **Monterey Formation.** The Monterey Formation records the filling of a deep basin formed by tectonism along the California margin and constitutes one of the major elements of California geology and can range up to several thousands of feet thick. The Monterey ranges in age from the Pliocene to middle Miocene and can be found throughout the basins of the Peninsular Ranges and Transverse Ranges provinces in the subsurface. The Monterey Formation has yielded a diverse fauna consisting of some mollusks and common fish skeletons, and remains of larger marine macrofauna such as whales and the giant extinct Desmostylus, as well as birds, crocodiles and rare land organisms such as horse and land plants (SWCA 2019). The UCMP collections hold at least 459 vertebrates from the Monterey Formation including birds, cartilaginous fish, bony fish, mammals, and reptiles. There are at least 18 different genera of marine mammals alone, attesting to the richness of the formation.
- **Vaqueros Formation.** The Vaqueros Formation consists of predominately limey sandstone interbedded with siltstone and shale deposited in an offshore basin. The Vaqueros Formation is common in the Peninsular Ranges and Transverse Ranges provinces and dates from the early Miocene to the late Eocene. Common fossils in the Vaqueros Formation include marine invertebrates such as barnacles, ostreids, pectinids and marine ichnofossils, as well as terrestrial vertebrates and marine megafauna (SWCA 2019).

Cenozoic Terrestrial Deposits

Cenozoic terrestrial deposits date from the Paleocene to the Pleistocene and were deposited in terrestrial environments as alluvial sediments, fluvial sediments, and lacustrine deposits. These geologic formations are well known for being highly fossiliferous in southern California and may preserve a wide variety of terrestrial fauna: invertebrates such as mollusks; plants; and abundant terrestrial vertebrates such as horse, camel, bison, and others.

These deposits are particularly common at the surface in the Mojave and Colorado Desert provinces but are found scattered across the entire SCAG region. Some of these units with the highest paleontological sensitivity (United States Bureau of Land Management [BLM] Potential Fossil Yield Classification System class 4 or 5, SVP high potential) are discussed below:

- **Pleistocene Alluvium.** Pleistocene Alluvium consists of sand, silt, and gravel deposited in terrestrial environments as the result of erosion of surrounding highlands and dates to the Pleistocene (11,700 to 2.6 million years ago). Pleistocene sediments have a rich fossil history in southern California (SWCA 2019).

  The most common Pleistocene terrestrial mammal fossils include the bones of mammoth, horse, bison, camel, and small mammals, but other taxa, including lion, cheetah, wolf, antelope, peccary, mastodon, capybara, and giant ground sloth, have been reported, as well as birds, amphibians, and reptiles such as frogs, salamanders, snakes, and turtles. In addition to illuminating the striking differences between Southern California in the Pleistocene and today, this abundant fossil record has been vital in studies of extinction, ecology, and climate change (SWCA 2019).

An excellent example of the striking abundance and diversity of these Pleistocene sediments comes from Riverside County, just south of San Bernardino County, where nearly 100,000 identifiable fossil specimens representing 105 vertebrate, invertebrate, and plant species were collected from more than 2,000 individual localities during the construction of the dam at Diamond Valley Lake and are now housed at the Western Science Center in Hemet, California. This site represents the second largest late Pleistocene fossil assemblage known from the American Southwest after the La Brea Tar Pits in Los Angeles. Other Ice Age fossils have been found throughout the inland valleys and the Mojave Desert (SWCA 2019).

- **Manix Formation.** The Manix Formation consists of around 40 meters of lacustrine, fluvial, and alluvial sediments deposited in and around the Middle to late Pleistocene Lake Manix (Reheis et al. 2012). This formation occurs to the east of Barstow in the Mojave Desert. The lacustrine and fluvial deposits in this formation have yielded a diverse fauna, preserving invertebrates such as mollusks and ostracods as well as aquatic and terrestrial vertebrates such as fish, birds, and numerous Ice Age mammals (Leatham and Kunath 2012). The UCMP collections attest to the diversity of species specimens associated with this formation with over 16 distinctive birds, 237 mammals, nine fish, and 7 reptiles, out of 316 vertebrate fossils.
- **San Timoteo Formation.** The San Timoteo Formation dates from the Pleistocene to the Pliocene and consists of stream-deposited alluvial sediments that are made up of detritus eroded from the San Bernardino Mountains in the Mojave Desert and southeastern Transverse Ranges provinces. A number of significant fossil deposits have been discovered in the San Timoteo and the UCMP collections contain over 21 different genera of mammals as well as reptiles. The construction of the El Casco Substation in San Timoteo Canyon between September 2009 and January 2011 produced numerous fossils, including riparian and aquatic plants, insects, slugs and snails, fish, tortoise, lizards, snakes, small mammals, birds, a giant camel, a llama, two ground sloths, and two different types of saber tooth cats. The Shutt Ranch fauna is a collection of hundreds of significant fossils belonging to 37 species of small mammals, as well as larger macrofauna such as sloth, camel, deer, horse, and others, found in the San Timoteo beds. The scientific literature records a rich fossil history from this unit that includes fossils of more than 30 plant taxa and over forty animal taxa, including camels, deer, sloth, elephants, bears, rabbits, and rodents. This fauna has been the subject of study for almost 100 years (SWCA 2019). Most recently, a unique sabertoothed cat was recovered that provided key information on the diet of the group (Dooley et al. 2012)
- **Avawatz Formation.** The Avawatz Formation consists of four members: conglomerate; siltstone and sandstone; breccias; and sandstone, siltstone, and tuff deposited in alluvial fans, floodplains, and lakes, spanning a period of around 40 million years, during the late Miocene. The Avawatz Formation is found in the Avawatz Mountains in the Mojave Desert province. The Avawatz preserves a typical Miocene mammalian fauna of early ancestors of horses and camels, as well as abundant rodents and some reptiles. In addition, the Avawatz Formation is known for preserving exceptional fossil trackways from dozens of different types of animals, including birds, camels, and cats (e.g., Reynolds and Milner, 2012). Trackways are significant fossil resources, and provide valuable information on not only foot morphology, but also how an animal moved and potentially whether it was part of a herd. The Raymond M. Alf Museum in Claremont, California, has more than 100 fossil trackways collected from the Avawatz Formation in San Bernardino County (SWCA 2019).
- **Topanga Group.** The Topanga Group of formations is predominantly composed of sandstone but also some siltstone, breccia, and shale. Formations within the Topanga Group are common across the basins of the Peninsular Ranges and Transverse Ranges provinces. The Topanga Group is interpreted to represent wave-dominated coastal deposits grading into river-dominated deltaic deposits and fluvial deposits in the upper parts of the formation. The formations within the Topanga Group date to the middle Miocene, around 20 to 16 million years ago. Fossils from these formations include numerous invertebrate and vertebrate remains

from both marine and terrestrial settings, including sharks, bony fishes, birds, whales, dolphins, and land mammals (SWCA 2019).

- **Barstow Formation.** The Barstow Formation is composed of fluvial and lacustrine sediments interbedded with air-fall tuff beds deposited in lakes from around 14.8 to 19.3 million years ago. This formation crops out across the Mojave Desert province. The fossil mammal fauna of the Barstow is so abundant it has been used to define a biostratigraphic portion of the middle Miocene called the Barstovian North American Land Mammal Age. The University of California, Berkeley, conducted extensive excavations of the mammal fossils shortly after they were first discovered in the Mud Hills. The most common fossils from the Barstow Formation include early ancestors of horses, antelope, and camels, as well as small mammals such as mice and rabbits, with birds, fish, invertebrates, reptiles, and early ancestors of canines and elephants less common but well represented. In addition to the vertebrate fauna, an extensive record of exceptionally preserved small organisms, such as insects and arthropods, are known from the Barstow Formation. These fossils have been extensively studied and reported on in the scientific literature, leading to a better understanding of the early evolution of many modern animals ranging from horses and camels to insects, as well as paleoecology (SWCA 2019). Additionally, the Barstow Formation has been used as a key deposit for understanding taphonomy, or the process of fossilization (Loughney and Badgley 2020). The vast collections hosted at the UCMP attest to the richness and diversity of the Barstow Formation. Over 4,000 specimens are in the online database, representing amphibians, eight distinct genera of birds, 75 different genera of mammals, and seven different reptiles.

3.7.2 Regulatory Framework

Regulations associated with geology, soils, and associated seismic and geologic hazards are summarized below. In addition, regulations applicable to paleontology and fossil resources are also addressed. Regulations related to erosion and sedimentation, which are primarily related to water quality issues, are provided in Section 3.10, *Hydrology and Water Quality*, of this 2024 PEIR.

Federal

Earthquake Hazards Reduction Act

The Earthquake Hazards Reduction Act of 1977 (Public Law 95-124) established the National Earthquake Hazards Reduction Program which is coordinated through the Federal Emergency Management Agency (FEMA), the USGS, the National Science Foundation, and the National Institute of Standards and Technology. The purpose of the Program is to establish measures for earthquake hazards reduction and promote the adoption of earthquake hazards reduction measures by federal, state, and local governments; national standards and model code organizations; architects and engineers; building owners; and others with a role in planning and constructing buildings, structures, and lifelines through (1) grants, contracts, cooperative agreements, and technical assistance; (2) development of standards, guidelines, and voluntary consensus codes for earthquake hazards reduction for buildings, structures, and lifelines; and (3) development and maintenance of a repository of information, including technical data, on seismic risk and hazards reduction. The Program is intended to improve the understanding of earthquakes and their effects on communities, buildings, structures, and lifelines through interdisciplinary research that involves engineering, natural sciences, and social, economic, and decisions sciences.

Disaster Mitigation Act (2000)

The federal Disaster Mitigation Act (DMA) (Public Law 106-390) provides the legal basis for FEMA mitigation planning requirements for state, local, and Tribal governments as a condition of mitigation grant assistance. DMA 2000 amended the Robert T. Stafford Disaster Relief and Emergency Assistance Act by repealing the previous mitigation planning provisions and replacing them with a new set of requirements that emphasize the need for state, local, and Indian Tribal entities to closely coordinate mitigation planning and implementation efforts. The requirement for a state mitigation plan is continued as a condition of disaster assistance, adding incentives for increased coordination and integration of mitigation activities at the state level through the establishment of requirements for two different levels of state plans. DMA 2000 also established a new requirement for local mitigation plans and authorized up to seven percent of Hazard Mitigation Grand Program funds available to a state for development of state, local, and Indian Tribal mitigation plans.

Clean Water Act Section 402

Section 402 of the Clean Water Act (33 U.S. Code Section 1251 et seq.) establishes a framework for regulating municipal and industrial stormwater discharges under the National Pollutant Discharge Elimination System (NPDES) program. The NPDES program controls water pollution by regulating point sources that discharge pollutants, including rock, sand, dirt, and agricultural, industrial, and municipal waste, into waters of the United States. USEPA has delegated to the State Water Resources Control Board the authority for the NPDES program in California, which is implemented by the State's nine Regional Water Quality Control Boards. Under the NPDES Phase II Rule, construction activity disturbing one or more acres must obtain coverage under the State's General Permit for Discharges of Storm Water Associated with Construction Activity (General Construction Permit). As described further in Section 3.10, *Hydrology and Water Quality*, the Construction General Permit requires that applicants develop and implement a stormwater pollution prevention plan (SWPPP), which specifies best management practices (BMP) that reduce pollution in stormwater discharges to the Best Available Technology Economically Achievable/Best Conventional Pollutant Control Technology standards and perform inspections and maintenance of all BMPs.

U.S. Geological Survey Landslide Hazard Program

The USGS Landslide Hazard Program provides information on landslide hazards including information on current landslides, landslide reporting, real time monitoring of landslide areas, mapping of landslides through the National Landslide Hazards Map, local landslide information, landslide education, and research.

Paleontological Resources Preservation Act

The primary legislation pertaining to fossils from the National Park Service and other federal lands is the Paleontological Resources Preservation Act of 2009 (PRPA) (16 U.S.C. § 470aaa 1-11), which was enacted on March 30, 2009, within the Omnibus Public Land Management Act of 2009 (NPS 2023). PRPA directs the Department of Agriculture (U.S. Forest Service) and the Department of the Interior (National Park Service, Bureau of Land Management, Bureau of Reclamation, and Fish and Wildlife Service) to manage and protect paleontological resources on Federal land using scientific principles and expertise. The Secretary shall develop appropriate plans for inventory, monitoring, and the scientific and educational use of paleontological resources, in accordance with applicable agency laws, regulations, and policies. These plans shall emphasize interagency coordination and collaborative efforts where possible with non-Federal partners, the scientific community, and the general public.

Additionally, the federal land managing agencies were directed to establish a program to increase public awareness about the significance of paleontological resources. The National Park Service established National Fossil Day to address this provision in the law and to promote the scientific and educational values of fossils. The National Fossil Day partnership consists of more than 380 partners across the U.S. including museums, science and teacher organizations, universities, libraries, agencies, fossil sites, amateur fossil groups and others interested in fossils.

PRPA provides specific mandates for administering paleontological resource research and collecting permits and the curation of fossil specimens in museum collections. The law also includes provisions for both criminal and civil penalties associated with paleontological resource crimes on federal lands.

Antiquities Act

In 1906, the Antiquities Act (54 U.S.C. § 320301–320303) was enacted to help protect any historic or prehistoric ruin or monument, or any object of antiquity, situated on lands owned or controlled by the Government of the United States (NPS 2023). The act further authorizes the President of the United States to declare national monuments by public proclamation of historic landmarks, historic and prehistoric structures, and other objects of historic or scientific interest on federal lands. The Antiquities Act was used to proclaim several national monuments based upon significant paleontological resources including Petrified Forest National Park, Dinosaur National Monument, Fossil Cycad National Monument (now abolished), and most recently Waco Mammoth National Monument.

State

Alquist-Priolo Earthquake Fault Zoning Act (Alquist-Priolo Act)

The Alquist-Priolo Act (California Code of Regulations, Section 3603(f)) provides policies and criteria to assist cities, counties, and state agencies to prevent the construction of buildings used for human occupancy on the surface trace of active faults. The Alquist-Priolo Act was intended to provide the citizens of the state with increased safety and to minimize the loss of life during and immediately following earthquakes by facilitating seismic retrofitting to strengthen buildings, including historical buildings, against ground shaking.

In accordance with the Act, the State Geologist has established regulatory zones—called earthquake fault zones—around the surface traces of active faults and has published maps illustrating these zones. The Act requires that special geologic studies be conducted to locate and assess any active fault traces in and around known active fault areas prior to development of structures for human occupancy. This state law was a direct result of the 1971 San Fernando Earthquake, which was associated with extensive surface fault ruptures that damaged numerous homes, commercial buildings, and other structures. The Act's main purpose is to prevent the construction of buildings used for human occupancy on the surface trace of active faults. This Act addresses only the hazard of surface fault rupture and is not directed toward other earthquake hazards. Because many active faults are complex and consist of more than one branch that may experience ground surface rupture, earthquake fault zones extend approximately 200 to 500 feet on either side of the mapped fault trace.

Seismic Hazards Mapping Act

The Seismic Hazards Mapping Act of 1990 (Public Resources Code [PRC] Chapter 7.8, Sections 2690–2699.6) addresses non-surface fault rupture earthquake hazards, including liquefaction and seismically induced landslides. The purpose of the Act is to protect the public from the effects of strong ground shaking, liquefaction, landslides, or other ground failure, and other hazards caused by earthquakes. The program and actions mandated by the Seismic Hazards Mapping Act closely resemble those of the Alquist-Priolo Act.

This act requires the State Geologist to delineate various seismic hazard zones, and cities, counties, and other local permitting agencies to regulate certain development projects within these zones. For projects that would locate structures for human occupancy within designated Zones of Required Investigation, the Seismic Hazards Mapping Act requires project applicants to perform a site-specific geotechnical investigation to identify the potential site-specific seismic hazards and corrective measures, as appropriate, prior to receiving building permits. The CGS Guidelines for Evaluating and Mitigating Seismic Hazards (Special Publication 117A) provides guidance for evaluating and mitigating seismic hazards.

California Building Code

The California Building Code (CBC), which is codified in Title 24 of the California Code of Regulations, Part 2, was promulgated to safeguard the public health, safety, and general welfare by establishing minimum standards related to structural strength, means of egress to facilities (entering and exiting), and general stability of buildings. The purpose of the CBC is to regulate and control the design, construction, quality of materials, use/occupancy, location, and maintenance of all buildings and structures. Title 24 is administered by the California Building Standards Commission, which, by law, is responsible for coordinating all building standards. Under State law, all building standards must be contained in Title 24 or they are not enforceable. The provisions of the CBC apply to the construction, alteration, movement, replacement, location, and demolition of every building or structure or any appurtenances connected or attached to such buildings or structures throughout California.

The 2022 edition of the CBC is based on the International Building Code (IBC) published by the International Code Council, which replaced the Uniform Building Code (UBC) in 2000. The code is updated triennially, and the 2022 edition of the CBC was published by the California Building Standards Commission on July 1, 2022, and took effect starting January 1, 2023. The 2022 CBC contains California amendments based on the American Society of Civil Engineers (ASCE) Minimum Design Standard ASCE/SEI 7-22, Minimum Design Loads for Buildings and Other Structures, provides requirements for general structural design and includes means for determining earthquake loads as well as other loads (such as wind loads) for inclusion into building codes. Seismic design provisions of the building code generally prescribe minimum lateral forces applied statically to the structure, combined with the gravity forces of the dead and live loads of the structure, which the structure then must be designed to withstand. The prescribed lateral forces are generally smaller than the actual peak forces that would be associated with a major earthquake. Consequently, structures should be able to (1) resist minor earthquakes without damage; (2) resist moderate earthquakes without structural damage but with some nonstructural damage; and (3) resist major earthquakes without collapse, but with some structural as well as nonstructural damage. Conformance to the current building code recommendations does not constitute any kind of guarantee that significant structural damage would not occur in the event of a maximum magnitude earthquake; however, it is reasonable to expect that a structure designed in accordance with the seismic requirements of the CBC should not collapse in a major earthquake.

The earthquake design requirements take into account the occupancy category of the structure, site class, soil classifications, and various seismic coefficients, all of which are used to determine a seismic design category (SDC) for a project. The SDC is a classification system that combines the occupancy categories with the level of expected ground motions at the site; SDC ranges from A (very small seismic vulnerability) to E/F (very high seismic vulnerability and near a major fault). Seismic design specifications are determined according to the SDC in accordance with CBC Chapter 16. CBC Chapter 18 covers the requirements of geotechnical investigations (Section 1803), excavation, grading, and fills (Section 1804), load-bearing of soils (Section 1806), as well as foundations

(Section 1808), shallow foundations (Section 1809), and deep foundations (Section 1810). For Seismic Design Categories D, E, and F, Chapter 18 requires analysis of slope instability, liquefaction, and surface rupture attributable to faulting or lateral spreading, plus an evaluation of lateral pressures on basement and retaining walls, liquefaction and soil strength loss, and lateral movement or reduction in foundation soil-bearing capacity. It also addresses measures to be considered in structural design, which may include ground stabilization, selecting appropriate foundation type and depths, selecting appropriate structural systems to accommodate anticipated displacements, or any combination of these measures. The potential for liquefaction and soil strength loss must be evaluated for site-specific peak ground acceleration magnitudes and source characteristics consistent with the design earthquake ground motions.

Requirements for geotechnical investigations are included in Appendix J, CBC Section J104, Engineered Grading Requirements. As outlined in Section J104, applications for a grading permit are required to be accompanied by plans, specifications, and supporting data consisting of a soils engineering report and engineering geology report. Additional requirements for subdivisions requiring tentative and final maps and for other specified types of structures are in California Health and Safety Code Sections 17953 to 17955 and in 2013 CBC Section 1802. Testing of samples from subsurface investigations is required, such as from borings or test pits. Studies must be done as needed to evaluate slope stability, soil strength, position and adequacy of load-bearing soils, the effect of moisture variation on load-bearing capacity, compressibility, liquefaction, differential settlement, and expansiveness.

California Department of Transportation (Caltrans) Regulations

Caltrans' jurisdiction includes rights-of-way (ROWs) of state and interstate routes within California. Any work within the ROW of a federal or state transportation corridor is subject to Caltrans' regulations governing allowable actions and modifications to the ROW. Caltrans issues permits to encroach on land within their jurisdiction to ensure encroachment is compatible with the primary uses of the State Highway System, to ensure safety, and to protect the state's investment in the highway facility. The encroachment permit requirement applies to persons, corporations, cities, counties, utilities, and other government agencies. A permit is required for specific activities including opening or excavating a state highway for any purpose, constructing, or maintaining road approaches or connections, grading within rights-of-way on any state highway, or planting or tampering with vegetation growing along any state highway. The encroachment permit application requirements relating to geology, seismicity and soils include information on road cuts, excavation size, engineering and grading cross-sections, hydraulic calculations, and mineral resources approved under Surface Mining and Reclamation Act of 1975 (SMARA).

Caltrans Seismic Design Criteria

Caltrans Seismic Design Criteria was initiated through the recognition that past earthquakes in California have shown the vulnerability of some older structures, designed with non-ductile design standards to earthquake-induced force sand deformations. As a result, Caltrans initiated an extensive seismic retrofit program to strengthen the state's inventory of bridges to ensure satisfactory performance during anticipated future earthquakes. Caltrans has funded an extensive research program as well as developed design procedures that have furthered the state of practice of earthquake bridge engineering. The Seismic Design Criteria are an encyclopedia of new and currently practiced seismic design and analysis methodologies for the design of new bridges in California. The Seismic Design Criteria adopts a performance-based approach specifying minimum levels of structural system performance, component performance, analysis, and design practices for ordinary standard bridges. Bridges with non-standard features or operational requirements above and beyond the ordinary standard bridge may require a greater degree of attention than specified by the Seismic Design Criteria.

SOUTHERN CALIFORNIA CATASTROPHIC EARTHQUAKE PREPAREDNESS PLAN

The Southern California Catastrophic Earthquake Preparedness Plan, based on the California Geological Survey and USGS's ShakeOut Scenario of 2008, was released in 2010 and examines the initial impacts, inventories resources, cares for those wounded and homeless, and develops a long-term recovery process. The process of Long-Term Regional Recovery (LTRR) provides a mechanism for coordinating federal support to state, tribal, regional, and local governments, nongovernmental organizations (NGO), and the private sector to enable recovery from long-term consequences of extraordinary disasters. The LTRR process accomplishes this by identifying and facilitating the availability and use of recovery funding sources and providing technical assistance (such as impact analysis) for recovery and recovery planning support. "Long term" refers to the need to reestablish a healthy, functioning region that would sustain itself over time. Long-term recovery is not debris removal and restoration of utilities, which are considered immediate or short-term recovery actions. The LTRR's three main focus areas are housing, infrastructure (including transportation), and economic development.

PUBLIC RESOURCES CODE SECTION 5097.5

PRC Section 5097.5 states that "no person shall knowingly and willfully excavate upon, or remove, destroy, injure, or deface, any historic or prehistoric ruins, burial grounds, archaeological or vertebrate paleontological site, including fossilized footprints, inscriptions made by human agency, rock art, or any other archaeological, paleontological or historic feature situated on public lands, except with the express permission of the public agency having jurisdiction over the lands."

LOCAL

COUNTY AND CITY GENERAL PLANS

A safety element is required in county and city general plans for the protection of the community from any unreasonable risks associated with the effects of seismically induced surface rupture, ground shaking, ground failure, slope instability leading to mudslides and landslides, subsidence, liquefaction, and other seismic hazards identified in PRC Division 2, and other geologic hazards known to the legislative body. The safety element shall include mapping of known seismic and other geologic hazards (Government Code Section 65302(g)). Table 3.7-1 and Map 3.7-2 above show the potentially active faults in the SCAG region. As part of the safety element, county and city governments typically identify goals, objectives, and implementing actions to minimize the loss of life, property damage, and disruption of goods and services from man-made and natural disasters including floods, fires, non-seismic geologic hazards, and earthquakes. County and City governments may provide policies and develop ordinances to ensure acceptable protection of people and structures from risks associated with these hazards. Ordinances may include those addressing unreinforced masonry construction, erosion, or grading.

3.7.3 Environmental Impacts

Thresholds of Significance

For the purposes of this 2024 PEIR, SCAG has determined that implementation of Connect SoCal 2024 could result in significant impacts related to geology and soils if the Plan would exceed the following significance criteria, in accordance with California Environmental Quality Act (CEQA) Guidelines Appendix G:

- Directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving:
  - (i) Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault? Refer to Division of Mines and Geology Special Publication 42.
  - (ii) Strong seismic ground shaking.
  - (iii) Seismic-related ground failure, including liquefaction.
  - (iv) Landslides.
- Result in substantial soil erosion or the loss of topsoil.
- Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse.
- Be located on expansive soil creating substantial direct or indirect risks to life or property.[8]
- Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater.
- Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature.

Methodology

Chapter 2, *Project Description*, describes the Plan's vision, goals, policies, forecasted regional development pattern, policies and strategies, and individual transportation projects and investments. The Plan aims to increase mobility, promote sustainability, and improve the regional economy. Although land use development is anticipated to occur within the region even without the Plan, the Plan could influence growth, including distribution patterns. To address this, the 2024 PEIR includes an analysis on the implementation of policies and strategies as well as potential projects and evaluates how conditions in 2050 under the Plan would differ from existing conditions. The analysis for geology and soils considered public comments received on the NOP and feedback and discussions at the various public and stakeholder outreach meetings.

The environmental analysis presented in this section evaluates the potential impacts of Connect SoCal 2024 implementation related to geology, soils, and paleontological resources. The potential for hazards to people and property from geology and soils conditions, as well as impacts to paleontological resources, was evaluated in accordance with Appendix G of the 2023 State California Environmental Quality Act (CEQA) Guidelines. Geology, soils, and paleontological resources impacts within the SCAG region were evaluated at the programmatic level of detail, in relation to the general plans of the six counties and the 191 cities within the SCAG region and is based

8 The CBC no longer includes a Table 18-1-B. Instead, Section 1803.5.3 of the CBC describes the criteria for analyzing expansive soils.

on a review of the results of the review of literature and database research (geologic, seismic, soils, and paleontological resources reports and maps).

Geology and Soils

The methodology for determining the significance of potential risk to people and property in relation to hazards posed by geology and soils compares the existing (2023) conditions to the future 2050 conditions under the Plan, as required by CEQA Guidelines Section 15126.2(a).

Transportation and land use projects resulting from policies and strategies envisioned in Connect SoCal 2024 would be regulated by the various laws, regulations, and policies summarized above in Section 3.7.2, *Regulatory Framework*. Compliance by projects with applicable federal, state, and local laws and regulations is assumed in this analysis, and local and state agencies would be expected to continue to enforce applicable requirements.

After considering the implementation of the Plan described in Chapter 2, *Project Description*, and compliance with the regulatory requirements, the environmental analysis below identifies if the significance thresholds have the potential to be exceeded and, therefore, whether a significant impact could occur. For those impacts considered to be significant, mitigation measures are proposed to the extent feasible to reduce the significance of identified impacts.

In compliance with existing regulations, the structural elements of transportation and land use projects resulting from policies and strategies envisioned in the Plan would undergo appropriate design-level geotechnical evaluations prior to final design and construction. Implementing the regulatory requirements in the CBC, Caltrans requirements, and city or county ordinances and ensuring that all buildings and structures constructed in compliance with the law is the responsibility of the project engineers and building officials. The geotechnical engineer[9] for each project, as a registered professional with the State of California, is required to comply with the CBC, Caltrans requirements, and local codes while applying standard engineering practice and the appropriate standard of care for the particular region in California, which, in the case of the Plan, would be the counties and cities within the SCAG region. The California Professional Engineers Act (Building and Professions Code Sections 6700-6799), and the Codes of Professional Conduct, as administered by the California Board of Professional Engineers and Land Surveyors, provides the basis for regulating and enforcing engineering practice in California. The local building officials are responsible for inspections and ensuring CBC, Caltrans requirements, and local code compliance prior to approval of the building permit, as well as inspections during and after construction to confirm implementation of associated requirements.

With regard to transportation and development projects resulting from policies and strategies in Connect SoCal 2024, given the uncertainties regarding the nature and specific locations of future development projects, impacts associated with geologic conditions and associated hazards are evaluated qualitatively based on the potential intersection of project footprints with areas having known geologic hazards taking into consideration the applicable regulations that address such hazardous conditions.

Note that in 2015, the California Supreme Court in *California Building Industry Association v. Bay Area Air Quality Management District* (*CBIA v. BAAQMD*) (2015) 62 Cal.4th 369), held that CEQA generally does not require a lead agency to consider the impacts of existing environmental conditions on the future residents or users of a project. There are two exceptions to this rule: First, "[W]hen a proposed project risks exacerbating those environmental

9 A geotechnical engineer (GE) specializes in structural behavior of soil and rocks. GEs conduct soil investigations, determine soil and rock characteristics, provide input to structural engineers, and provide recommendations to address problematic soils.

hazards or conditions that already exist, an agency must analyze the potential impact of such hazards on future residents or users." (Id. at p. 377.) Second, "[S]pecial CEQA requirements apply to certain airport, school, and housing construction projects. In such situations, CEQA requires agencies to evaluate a project site's environmental conditions regardless of whether the project risks exacerbating existing conditions." (Id. at p. 378.) In the area of housing, these special statutes limit "the availability of CEQA exemptions where future residents or users of certain housing development projects may be harmed by existing conditions." (Id. at p. 391.)

If a project risks exacerbating preexisting environmental hazards or conditions, the lead agency is required to analyze the impact of that exacerbated condition on the environment, which may include future residents and users within the project area. While transportation and land use projects under the Plan would not generally exacerbate existing environmental hazards related to geological and soil conditions, consistent with past practice, information is presented on geologic hazards at the regional level.

Paleontological Resources

With regard to evaluation of paleontological resources impacts, various agencies and professional societies define significance of fossil deposits differently, but the commonality is (1) to protect resources that are rare (such as vertebrate fossils) or are in jeopardy of loss through looting or destructive activities, and (2) to record unique conditions (such as Pleistocene playa lakes). To best manage resources, the standard practice is to initially define the significance based on published, mappable geological formations. The higher the mapping resolution, the more accurate the evaluation. Specific projects can then be quickly assessed and, if necessary, be assigned higher-detail scrutiny.

For this section, the recommendations of SVP are followed as they are the industry standard for non-federal projects. The SVP (2010) defines fossils as being over 5,000 years in age, while the BLM (2016) generally considers fossils to be Pleistocene in age or older (11,700 years in age). Therefore, sediments younger than middle or early Holocene are too young to preserve fossil resources and have low paleontological sensitivity. Other types of geologic units with low sensitivity are moderately metamorphosed rocks, as the heat and pressure associated with metamorphism is likely to destroy fossils. High grade metamorphic rocks, as well as igneous rocks, have no paleontological sensitivity. For the purposes of analysis of potential impacts, similar to geology and soils impacts, the transportation projects and land use projects resulting from policies and strategies envisioned in Connect SoCal 2024 were evaluated based on their general locations relative to paleontologically sensitive geologic formations in order to determine the potential for such projects to result in adverse impacts to (i.e., damage to or the destruction of) fossil resources during Plan implementation.

Geology and Soils and Paleontological Resources

As discussed in Chapter 2, *Project Description*, and Section 3.0, *Introduction to the Analysis*, Connect SoCal 2024 includes Regional Planning Policies and Implementation Strategies, some of which will effectively reduce impacts in the various resource areas. Furthermore, compliance with all applicable laws and regulations (as set forth in the Regulatory Framework) would be reasonably expected to reduce impacts of the Plan. See CEQA Guidelines Section 15126.4(a)(1)(B). As discussed in Section 3.0, where remaining potentially significant impacts are identified, SCAG mitigation measures are incorporated to reduce these impacts. If SCAG cannot mitigate impacts of the Plan to less than significant, project-level mitigation measures are identified that can and should be considered and implemented by lead agencies as applicable and feasible.

IMPACTS AND MITIGATION MEASURES

IMPACT GEO-1 **Directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving (i) rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault? Refer to Division of Mines and Geology Special Publication 42; (ii) strong seismic ground shaking; (iii) seismic-related ground failure, including liquefaction; (iv) landslides.**

Significant and Unavoidable Impact – Mitigation Required

Implementation of the Plan would result in projects exposed to both direct and indirect effects of seismic activities compared to existing conditions. Connect SoCal 2024 identifies new transit and rail routes, and the expansion of highway routes and other facilities, all of which would facilitate growth and associated development projects in the region. The Plan also aims to concentrate growth in specific areas by encouraging land use development within existing urban centers, walkable mixed-use communities, transit-oriented development, and other areas well-served by transit such as Transit Priority Areas (TPA), Neighborhood Mobility Areas (NMA), Livable Corridors, and other Priority Development Areas (PDAs). Projects implemented under the Plan are anticipated to be subject to seismic events to some degree over the life of projects because the Southern California region is seismically active. Projects implemented as a result of Connect SoCal 2024 generally would not be expected to exacerbate seismic conditions in the region but may increase the number of people exposed to seismic-related hazards.

Seismic events can damage transportation infrastructure and land use development through surface rupture, ground shaking, liquefaction, and landslides. As listed in Table 3.7-1, numerous active faults are known to exist in the SCAG region that could potentially generate seismic events capable of significantly affecting existing structures as well as future projects implemented consistent with the Plan. Also, as described in Section 3.7.1, *Environmental Setting*, it is expected there are unknown faults (e.g., blind thrust faults) that could also significantly damage transportation infrastructure or the built environment, including future projects implemented under Connect SoCal 2024. The Alquist-Priolo Earthquake Fault Zoning Act prohibits the location of structures for human occupancy across active faults. Local jurisdictions require a surface fault rupture hazard investigation for any development project that would be located within an Alquist-Priolo Earthquake Fault Zone. This is to ensure that proposed development would not be located astride an active fault. Given compliance with applicable requirements of the Alquist-Priolo Earthquake Fault Zoning Act and related building codes, no habitable structures associated with anticipated land use projects under the Plan would be constructed along, and therefore would not be subject to fault rupture from, known active faults. Further, transportation projects that traverse an Alquist-Priolo Earthquake Fault Zone, or that are located within 1,000 feet of an unzoned fault (not located in an Alquist–Priolo Earthquake Fault Zone) that is Holocene (up to 11,000 years) or younger in age, would be subject to fault rupture screening and, if warranted, a Surface Fault Rupture Displacement Hazard Analysis (Caltrans 2022). Based on the results of the analysis for a given facility (bridges, tunnels, buried reinforced concrete boxes [RCB], or buildings), improvements would normally be designed to accommodate anticipated displacements if a seismic event were to occur, such that substantial risks to life or property would be minimized.

The Plan contains projects that could be located in areas susceptible to seismic shaking and seismic-induced ground failures (i.e., landslide, liquefaction, and lateral spreading). Indirect impacts could also result in additional delays and breaks in service while repairs are made. The potential for such projects to be significantly affected by liquefaction would be higher in areas exhibiting shallow groundwater levels and unconsolidated soils such as fill material, some alluvial soils, and coastal sands.

Potential hazards associated with seismic shaking and seismic-induced ground failures (i.e., liquefaction, lateral spreading, landslides) would generally be addressed through site-specific geotechnical studies required by local jurisdictions in accordance with standard industry practices and state-provided guidance, such as the CBC, which addresses all seismic hazards, and CGS Special Publication 117A, which specifically address liquefaction.

Furthermore, the Plan itself would neither cause nor exacerbate existing geologic hazards, including the likelihood of fault rupture, because projects implemented under the Plan are not expected to include the injection or extraction of oil or groundwater, which could trigger movement along a fault.

Some transportation projects under the Plan would be located in proximity to known active faults, and further, increases in population would also result in additional people being located near known active faults. Potential direct impacts from surface rupture and severe ground shaking could cause damage to transportation infrastructure, including overpasses and underground structures. Indirect impacts from seismic events could damage ancillary transportation facilities such as port facilities, traffic control equipment, and train stations. With regard to land use development, seismic activity can cause damage to existing structures due to substandard construction. Increased density resulting from Plan could also increase the number of people and structures exposed to potential fault rupture at a given location. For example, if a fault were to rupture adjacent to an urban center more people would be affected than if fault rupture were to occur in a remote area of the region with few people (as was the case with the Ridgecrest earthquake). Strength of a particular earthquake and proximity to the fault would also be factors in how many people are affected by an earthquake. Further, as noted above, earthquakes can occur within previously undetected fault zones. For example, and as discussed in Section 3.7.1, *Environmental Setting*, the July 2019 Ridgecrest earthquakes occurred within previously undetected fault zones and caused an excess of $100 million in damages. A substantial earthquake along the San Andreas Fault Zone would have the potential to cause extensive fatalities, financial damages, and displacement of large numbers of people.

As required by California law, any new development would be subject to the seismic design criteria of the CBC, Caltrans requirements, and city or county building codes, which require that all improvements be constructed to withstand anticipated ground shaking and seismic-induced ground failures from regional fault sources. Each development project would typically be required to obtain approval of a site-specific geotechnical report prior to the issuance of individual grading permits; applicants for all development projects would be required to retain a licensed geotechnical engineer to design new structures to withstand probable seismically induced ground shaking. Adherence to the applicable CBC requirements and city codes would ensure that majority of projects developed under the Plan would not directly or indirectly cause substantial adverse effects, including the risk of loss, injury, or death involving strong seismic ground shaking or seismic-induced ground failures. New or seismically retrofitted structures designed with current state of the art engineering knowledge and compliance with local or state building codes (California Building Code, Uniform Building Code) also reduce potential damage to structures and minimize the seismic impacts to the public under these circumstances.

Although compliance with existing building codes and other regulations would address most geologic hazards associated with surface fault rupture, seismic ground shaking, ground failure, liquefaction, and landslides, given the size and geologic diversity of the region and associated uncertainties regarding the nature and location of future development, as well as uncertainty regarding enforcement of regulations, it is possible that some projects could exacerbate existing geologic conditions thus resulting in a significant impact. As such, impacts are considered significant and mitigation is required.

MITIGATION MEASURES

SCAG MITIGATION MEASURES

See **SMM-GEN-1**.

PROJECT-LEVEL MITIGATION MEASURES

PMM-GEO-1 In accordance with provisions of Sections 15091(a)(2) and 15126.4(a)(1)(B) of the State CEQA Guidelines, a Lead Agency for a project can and should consider mitigation measures to minimize the potential for adverse effects associated with surface fault rupture, seismic ground shaking, seismic-related ground failure, liquefaction, and landslides for projects located on sites with unusual geologic conditions, the following measures shall be considered:

- Use interim precautionary steps during construction to maintain ground surface and slope stability;
- Incorporate design and structural features that exceed the requirements of the applicable building code(s) as appropriate; and
- Utilize innovative design techniques for buildings and other structural elements located on sites with unique geologic conditions to ensure that projects do not exacerbate risks associated with existing conditions.

LEVEL OF SIGNIFICANCE AFTER MITIGATION

As previously discussed, the Plan's Regional Planning Policies and Implementation Strategies (see Chapter 2, *Project Description*, and Section 3.0, *Introduction to the Analysis*), compliance with existing laws and regulations would reduce impacts, but given the regional scale of the analysis in this 2024 PEIR, it is not possible or feasible to determine if all impacts would be fully mitigated. Therefore, this 2024 PEIR identifies SCAG and project-level mitigation measures. At the project level, lead agencies can and should consider the identified project-level mitigation measures during subsequent review of transportation and land use projects as appropriate and feasible. While the mitigation measures will reduce the impacts related to earthquake fault rupture, strong seismic ground shaking, seismic-related ground failure including liquefaction, and landslides, due to the regional nature of the analysis, unknown site conditions and project-specific details, and SCAG's lack of land use authority over individual projects, SCAG finds that the impact could be ***significant and unavoidable*** even with mitigation.

IMPACT GEO-2 **Result in substantial soil erosion or the loss of topsoil.**

Significant and Unavoidable Impact – Mitigation Required

Implementation of Connect SoCal 2024, particularly construction projects involving large-scale ground disturbance such as grade separation projects, mixed flow lane projects, and rail projects may result in significant impacts from soil erosion or the loss of topsoil. In addition, although the anticipated regional development pattern that directs more growth into PDAs including existing urban areas, walkable mixed-use communities, and areas well-served by transit such as TPAs, NMAs, and livable corridors, would generally be expected to have a lower potential to result in substantial soil erosion given the urbanized nature of such areas, it is possible that some projects could result in soil erosion or loss of topsoil constituting a potentially significant impact. Soil erosion and its subsequent loss are the result of the actions of water and wind. The likelihood of erosion is higher with an increase in slope, the narrowing of runoff channels, and the removal of groundcover such as vegetation. Human activities associated with development such as grading, particularly on slopes, increase the risk for erosion in affected areas. Erosion and loss of topsoil are concerns in the context of geology and soils since these processes, if occurring under, adjacent to, or even in proximity to transportation facilities, structures, or other improvements, can destabilize structural foundations and potentially result in damage to affected buildings and facilities, particularly in conjunction with seismic events. Loss of topsoil can also decrease the agricultural productivity of farmland, including potential adverse effects on Prime Farmland, Unique Farmland, and Farmland of Statewide Importance (refer to Section 3.2, *Agriculture and Forestry Resources*, of this 2024 PEIR for further discussion of potential impacts to farmland resulting from implementation of the Plan). Erosion also increases the risks of dust storms, which can degrade air quality (refer to Section 3.3, *Air Quality*, of this 2024 PEIR for further discussion of dust-related air quality impacts).

Some projects resulting from Plan implementation would involve major construction of new facilities that may involve rail lines, highway segments, or other anticipated development patterns that would be within previously undisturbed areas, which may result in soil erosion and the loss of topsoil. Additionally, some projects may also require significant earthwork including cuts into hillsides, which could become unstable over time, increasing long-term erosion potential. Plan policies and strategies that encourage denser development could also contribute to loss of topsoil through more widespread construction of underground parking garages. Improvements and modifications to existing ROWs, such as high-occupancy vehicle lanes, high-occupancy toll lanes, new busways and capacity enhancement facilities, mixed flow lanes, and ROW maintenance activities, would have less potential to impact topsoil because these project locations have previously been disturbed. However, road cuts could expose soils to erosion over the life of the project, creating potential landslide and falling rock hazards. Engineered roadways could be undercut over time by storm water drainage and wind erosion. Some areas would be more susceptible to erosion than others due to the naturally occurring soils with high erosion potential.

Notwithstanding natural soil types, engineered soils can also erode due to poor construction methods and design features or lack of maintenance. Projects implemented under the Plan could be located be in areas susceptible to geologic hazards including high soil erodibility. Construction of additional lanes on freeways, other transportation facilities or development could also potentially result in the loss of topsoil, through grading, trenching, excavation, and/or soil removal.

Construction activities for projects implemented under the Plan would involve ground-disturbing earthwork that could include removal of existing buildings and paved areas, soil excavation and backfilling, trenching, and grading. These activities could increase the susceptibility of soils on project sites to erosion by water (i.e., stormwater) or wind. During construction, heavy equipment such as bulldozers, graders, earth movers, heavy trucks, trenching equipment, and other machinery is likely to be used. Such machinery could contribute pollutants to stormwater runoff in the form of sediment, fuels, oil, lubricants, hydraulic fluid, or other contaminants. Additionally, site work could result in conditions of runoff. Sediment, silt, and construction debris, if mobilized during construction, could be transported to receiving waters. In the absence of runoff controls, exceedances of water quality standards could result. If not controlled and managed, the impact of soil erosion could be significant.

As discussed in greater detail in Section 3.10, *Hydrology and Water Quality*, of this 2024 PEIR, construction of future projects would typically require disturbance of more than one acre and thus would be required to apply for coverage under the State Construction General Permit to comply with federal NPDES regulations. A site-specific SWPPP would be developed and implemented as part of each future project in accordance with the Construction General Permit to prevent water quality impacts during demolition and construction activities. The SWPPP would include BMPs designed to control and reduce soil erosion. Examples of typical construction BMPs include scheduling or limiting certain activities to dry periods, installing sediment barriers such as silt fences and fiber rolls to trap sediment, and maintaining equipment and vehicles used for construction. Non-stormwater management measures include installing specific discharge controls during certain activities, such as paving operations, vehicle and equipment washing and fueling. In addition, all state projects for which Caltrans is the sponsor agency would be required to comply with the Caltrans Statewide NPDES permit that regulates all stormwater discharges from Caltrans owned conveyances, maintained facilities, and construction activities. The Caltrans Statewide NPDES permit also requires the implementation of similar BMPs. The inclusion of runoff control measures during construction activities of future projects would generally prevent adverse impacts to water quality under normal circumstances.

Stormwater runoff from operation of future projects implemented under the Plan would potentially contain pollutants common in urban and transportation runoff, including sediment, fuels and oils, metals, pesticides and herbicides, nutrients, and trash. Pollutants in stormwater runoff from urban development would have the potential to adversely impact water quality if the types and amounts are not adequately controlled or treated. Improper project design could result in increased runoff from sites that could result in erosion or loss or topsoil. Increased runoff could also result in exceeding that capacity of existing stormwater systems that could result in erosion or loss of topsoil.

Stormwater runoff from the types of urban uses that would result from implementation of the Plan would be regulated under the Municipal Stormwater Program (i.e., the Municipal Separate Storm Sewer System [MS4] or Municipal Regional Permit or Caltrans Statewide Storm Water Permit depending on the project location), as discussed in Section 3.10.2, *Regulatory Framework*, in Section 3.10, *Hydrology and Water Quality*, of this 2024 PEIR. Project applicants would be required to submit project design plans to the appropriate regulatory agency to demonstrate that the operation of their project would comply with the applicable permit requirements. The requirements include capturing and treating stormwater prior to exiting the project site and designing the stormwater system so as to not exceed the capacity of the local stormwater system into which the stormwater is discharged. BMPs included in site designs and plans for proposed projects would be reviewed by the relevant agency's engineering staff to ensure adequate treatment and design capacity prior to permit issuance. The review and permitting process would ensure that the permit's waste discharge requirements would not be violated by future projects. The BMPs would include stormwater collection and treatment systems with measures such as infiltration galleries, bioswales, bioretention basins, and storage and reuse of stormwater for landscaping.

The implementation of these types of BMPs required by the permits would typically prevent adverse impacts to water quality under normal circumstances. In addition to MS4 and Caltrans stormwater requirements, and as discussed in Section 3.10, *Hydrology and Water Quality*, of this 2024 PEIR, most jurisdictions in the SCAG region have adopted low-impact development (LID) requirements for all development projects, and many agencies are incorporating such LID features into their MS4 permit requirements (see discussion in Regulatory Framework in Section 3.10, *Hydrology and Water Quality*). LID is a set of stormwater management strategies that reduces impervious surfaces, treats runoff, controls runoff peaks and durations, and thereby helps protect water quality and the integrity of downstream receiving water bodies from water-borne pollutants including eroded soil materials. Projects less than an acre not subject to LID regulations may have minor site-specific impacts but such impacts are not anticipated to be significant or contribute to a regional-scale impacts. With compliance with existing permits, operation of the majority of future projects under the Plan would not violate any waste discharge requirements or otherwise substantially degrade water quality. However, while compliance with existing stormwater regulations would adequately address the vast majority of impacts associated with soil erosion and loss of topsoil, given the size and geologic diversity of the region and associated uncertainties regarding the nature and location of future development as well as regulatory enforcement, it is possible that some projects could result in substantial soil erosion or loss of topsoil, which would cause a significant impact. As such, impacts are considered significant and mitigation is required.

Mitigation Measures

SCAG Mitigation Measure

See **SMM-GEN-1**.

Project-Level Mitigation Measures

PMM-GEO-2 In accordance with provisions of Sections 15091(a)(2) and 15126.4(a)(1)(B) of the State CEQA Guidelines, a Lead Agency for a project can and should consider mitigation measures to reduce substantial adverse effects related to geologic hazards. Such measures may include the following or other comparable measures identified by the Lead Agency:

a) While compliance with the various municipal regional stormwater permits (MS4) is required by law, not all areas are necessarily covered. For those areas that are not covered under a municipal stormwater permit (MS4), consistent with the requirements of the SWRCB and local regulatory agencies with oversight of development associated with the Plan, ensure that project designs provide adequate slope drainage and appropriate landscaping to minimize the occurrence of slope instability and erosion. Design features should include measures to reduce erosion caused by stormwater. Road cuts should be designed to maximize the potential for revegetation.

Level of Significance after Mitigation

As previously discussed, the Plan's Regional Planning Policies and Implementation Strategies (see Chapter 2, *Project Description*, and Section 3.0, *Introduction to the Analysis*), compliance with existing laws and regulations would reduce impacts, but given the regional scale of the analysis in this 2024 PEIR, it is not possible or feasible to determine if all impacts would be fully mitigated. Therefore, this 2024 PEIR identifies SCAG and project-level mitigation measures. At the project level, lead agencies can and should consider the identified project-level mitigation measures during subsequent review of transportation and land use projects as appropriate and feasible. While the mitigation measures will reduce the impacts related to substantial soil erosion and loss of topsoil, due to the regional nature of the analysis, unknown site conditions and project-specific details, and SCAG's lack of land use authority over individual projects, SCAG finds that the impact could be ***significant and unavoidable*** even with mitigation.

IMPACT GEO-3 **Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse.**

Significant and Unavoidable Impact – Mitigation Required

Liquefaction and lateral spreading are most induced by seismic shaking, which is addressed in the discussion for Impact GEO-1 above. Subsidence has historically occurred within the SCAG region due to groundwater overdraft, mining activities, and petroleum extraction; projects implemented under the Plan are not anticipated to include any of these activities.

Slope failure results in landslides from unstable soils or geologic units. As discussed above, construction of transportation projects included in the Plan and future land use projects may require substantial earthwork and road cuts, increasing the potential for slope failures, such as landslides or collapse.

Hazards associated with unstable soils or geologic units are dependent on site-specific conditions, as well as the specific nature of the individual project proposed. Projects implemented under the Plan would typically be subject to appropriate design-level geotechnical evaluations prior to final design and construction, as required by the CBC, Caltrans requirements, and local building codes, as appropriate. Implementing the regulatory requirements in the CBC, Caltrans, and local ordinances and ensuring that all buildings and structures are constructed in compliance with applicable regulations is the responsibility of the project engineers and building officials within each jurisdiction. The geotechnical engineer, as a registered professional with the State of California, is required to comply with the CBC, Caltrans, and local codes while applying standard engineering practice and the appropriate standard of care for the particular region in California. The California Professional Engineers Act (Building and Professions Code Sections 6700-6799), and the Codes of Professional Conduct, as administered by the California Board of Professional Engineers and Land Surveyors, provides the basis for regulating and enforcing engineering practice in California. The local building officials are responsible for inspections and ensuring compliance prior to approval and issuance of the building permit for each project.

With adherence to grading permit and building code requirements, including seismic design criteria as required by the CBC, Caltrans, and local codes, transportation projects and anticipated land use projects would, under normal circumstances, be designed to minimize potential risks related to unstable soils and geologic units. Cities and counties would impose the recommended design parameters as a condition of any required planning approval, and compliance would be ensured through plan checks and development review processes. Nonetheless, while compliance with existing building codes and other regulations would address most geologic hazards associated with landslide, lateral spreading, subsidence, liquefaction, or collapse, given the size and geologic diversity of the region and associated uncertainties regarding the nature and location of future development and regulatory enforcement, it is possible that some projects could exacerbate existing geologic conditions thus resulting in a significant impact. Therefore, impacts associated with landslide, lateral spreading, subsidence, liquefaction, or other collapse resulting from implementation of the Plan are considered significant and mitigation is required.

Mitigation Measures

SCAG Mitigation Measure

See **SMM-GEN-1**.

PROJECT-LEVEL MITIGATION MEASURES

See **PMM-GEO-1**.

LEVEL OF SIGNIFICANCE AFTER MITIGATION

As previously discussed, the Plan's Regional Planning Policies and Implementation Strategies (see Chapter 2, *Project Description*, and Section 3.0, *Introduction to the Analysis*), compliance with existing laws and regulations would reduce impacts, but given the regional scale of the analysis in this 2024 PEIR, it is not possible or feasible to determine if all impacts would be fully mitigated. Therefore, this 2024 PEIR identifies SCAG and project-level mitigation measures. At the project level, lead agencies can and should consider the identified project-level mitigation measures during subsequent review of transportation and land use projects as appropriate and feasible. While the mitigation measures will reduce the impacts related to landslides, lateral spreading, subsidence, liquefaction, or collapse, due to the regional nature of the analysis, unknown site conditions and project-specific details, and SCAG's lack of land use authority over individual projects, SCAG finds that the impact could be ***significant and unavoidable*** even with mitigation.

IMPACT GEO-4 **Be located on expansive soil creating substantial risks to life or property.**

Significant and Unavoidable Impact – Mitigation Required

Projects implemented under the Plan, particularly projects involving large-scale ground disturbance during construction such as grade separation projects, mixed flow lane projects, and rail projects, and compact development strategies, may expose people and structures to risks where located on expansive soils. Soils with high percentages of clay can expand when wet, causing structural damage to surface improvements. These clay soils can occur in localized areas throughout the SCAG region. Failure to conduct geotechnical investigations to identify and implement recommendations to address expansive soil could ultimately result in damage to structures and roadways.

As discussed above in Impact GEO-3, projects implemented under the Plan would normally be required to undergo appropriate design-level geotechnical evaluations prior to final design and construction, as required by the CBC, Caltrans building requirements, and local building codes and ordinances. This would include investigating a given site for the presence of expansive soils and, if present, providing geotechnical recommendations to address such soils. Recommendations could consist of removal of expansive soils and replacement with imported engineered fill or treating the expansive soils to reduce the expansive potential (e.g., lime treatment). Local building officials for affected jurisdictions would be responsible for inspections and ensuring compliance prior to approval of building permits.

Expansive soil conditions would typically be addressed through the integration of geotechnical information in the design process for development projects to determine whether a site is suitable for a project. Compliance with CBC, Caltrans, and local building codes and ordinances would reduce hazards relating to expansive soils for the vast majority of projects. In addition, industry practice and state-provided guidance would further minimize risk associated with geologic hazards. However, even though compliance with existing building codes and other regulations would address most geologic hazards associated with expansive soils, given the size and geologic diversity of the region and associated uncertainties regarding the nature and location of future development and regulatory enforcement, it is possible that some projects could exacerbate existing geologic conditions thus resulting in a significant impact. Therefore, impacts associated with expansive soils resulting from implementation of the Plan are considered significant and mitigation is required.

Mitigation Measures

SCAG Mitigation Measure

See **SMM-GEN-1**.

Project-Level Mitigation Measures

See **PMM-GEO-1**.

Level of Significance after Mitigation

As previously discussed, the Plan's Regional Planning Policies and Implementation Strategies (see Chapter 2, *Project Description*, and Section 3.0, *Introduction to the Analysis*), compliance with existing laws and regulations would reduce impacts, but given the regional scale of the analysis in this 2024 PEIR, it is not possible or feasible to determine if all impacts would be fully mitigated. Therefore, this 2024 PEIR identifies SCAG and project-level mitigation measures. At the project level, lead agencies can and should consider the identified project-level mitigation measures during subsequent review of transportation and land use projects as appropriate and feasible. While the mitigation measures will reduce the impacts related to expansive soils, due to the regional nature of the analysis, unknown site conditions and project-specific details, and SCAG's lack of land use authority over individual projects, SCAG finds that the impact could be ***significant and unavoidable*** even with mitigation.

IMPACT GEO-5 **Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater.**

Significant and Unavoidable Impact – Mitigation Required

The Plan includes policies, strategies and investments intended to produce denser development in well-served transit areas. These policies, strategies, and investments encourage compact development in PDAs, and more walkable, mixed-use communities to accommodate the anticipated growth of over 2 million people by 2050. The Plan does not encourage or anticipate residential development in areas where sewers are not available for the disposal of wastewater or where densities would not support the provision of sanitary sewers. The Plan's transportation projects would not require septic tanks or alternative wastewater disposal systems. Moreover, the PDAs identified in the Plan are well served by sanitary sewer systems. To the extent septic tanks and alternative wastewater disposal systems may be required in more rural areas, septic tanks and alternative wastewater disposal systems are heavily regulated at the state, regional, and local level. Local jurisdictions also have general plans that contain policies and implementation measures, including BMPs relevant to the use of septic tanks or alternative water disposal systems. County environmental health departments typically regulate septic tanks through measures such as requiring a Sewage Disposal Permit for construction, reconstruction, repair, or abandonment of septic tanks. However, while regulation of septic systems by various agencies including County health departments would generally address most potential impacts associated with soils incapable of supporting the use of such systems, given the size and geologic diversity of the region and associated uncertainties regarding the nature and location of future development and regulatory enforcement, it is possible that some projects could cause localized adverse impacts on affected soils and geologic units thus resulting in a significant impact. Therefore, impacts from having soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater are considered significant, and mitigation measures are required.

MITIGATION MEASURES

SCAG MITIGATION MEASURE

See **SMM-GEN-1**.

LEVEL OF SIGNIFICANCE AFTER MITIGATION

As previously discussed, the Plan's Regional Planning Policies and Implementation Strategies (see Chapter 2, *Project Description*, and Section 3.0, *Introduction to the Analysis*), compliance with existing laws and regulations would reduce impacts, but given the regional scale of the analysis in this 2024 PEIR, it is not possible or feasible to determine if all impacts would be fully mitigated. Therefore, this 2024 PEIR identifies SCAG and project-level mitigation measures. At the project level, lead agencies can and should consider the identified project-level mitigation measures during subsequent review of transportation and land use projects as appropriate and feasible. While the mitigation measures will reduce the impacts related to soils incapable of supporting the use of septic tanks or alternative wastewater disposal systems, due to the regional nature of the analysis, unknown site conditions and project-specific details, and SCAG's lack of land use authority over individual projects, SCAG finds that the impact could be ***significant and unavoidable*** even with mitigation.

IMPACT GEO-6 **Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature.**

Significant and Unavoidable Impact – Mitigation Required

The diverse geological settings throughout the SCAG region span the entire range of sensitivities for paleontological resources. The focus of the following analysis is on the most sensitive geological units in the region, characterized by their distinguishing environments and ages. Each of these geologic units has a proven record of yielding sensitive paleontological resources.

Potential impacts to paleontological resources would be more likely to occur from ground-disturbing activities associated with implementation of the Plan rather than during ongoing operations. Although projects implemented under Connect SoCal 2024 would be subject to applicable requirements of the Paleontological Resources Preservation Act, the Antiquities Act, California PRC Section 5097.5, adopted county and city general plans, and other federal, state and local regulations, direct permanent impacts to paleontological resources as a result of the Plan may result from ground disturbance associated with construction. Ground-disturbing activities such as excavation for building foundations and bridges, trenching for utility lines, tunneling, and grading, could damage or destroy sensitive paleontological resources on or near the surface or at depth. Construction in previously undisturbed areas and deep excavation activities would have the greatest probability to impact intact buried paleontological resources. The potential for direct impacts to paleontological resources may be comparatively less for improvements to existing facilities and modifications to existing rights-of-way since these areas have been previously disturbed. However, any construction in geologic units with paleontological resources sensitivity could result in potentially significant damage to or destruction of unique paleontological resources.

Direct permanent impacts may arise if paleontological resources cannot be completely avoided by project design. Substantial damage to or destruction of significant paleontological resources would represent a significant impact. Excavation of the sediments and any significant fossils could destroy or degrade the condition of the fossils; additionally, the nature of project excavation would cause any fossils to be removed from their stratigraphic context, thereby reducing the scientific usefulness of the fossil. The extensive distribution and presence of rock units below the ground surface that may contain significant fossilized remains makes it difficult to predict the location of paleontological resources during the project planning phase, and thus increases the likelihood of inadvertent discovery of significant paleontological resources during construction and ground-disturbing activities. Therefore, the Plan has the potential to result in substantial alteration or removal of significant paleontological resources from construction activities, and therefore impacts are considered significant and mitigation is required.

Mitigation Measures

Project-Level Mitigation Measures

PMM-GEO-3 In accordance with provisions of Sections 15091(a)(2) and 15126.4(a)(1)(B) of the State CEQA Guidelines, a Lead Agency for a project can and should consider mitigation measures to reduce substantial adverse effects related to paleontological resources. Such measures may include the following or other comparable measures identified by the Lead Agency:

a) For sites where the presence of paleontological resources is considered possible, as appropriate obtain review by a qualified paleontologist (meets the SVP standards for a Principal Investigator or Project Paleontologist or the Bureau of Land Management (BLM) standards for a Principal Investigator), to determine if the project has the potential to require ground disturbance of parent material with potential to contain unique paleontological or resources, or to require the substantial alteration of a unique geologic feature. The assessment should include museum records searches, a review of geologic mapping and the scientific literature, geotechnical studies (if available), and potentially a pedestrian survey, if units with paleontological potential are present at the surface.

b) Avoid exposure or displacement of parent material with potential to yield unique paleontological resources.

c) Where avoidance of parent material with the potential to yield unique paleontological resources is not feasible:

    1) All on-site construction personnel receive Worker Education and Awareness Program (WEAP) training prior to the commencement of excavation work to understand the regulatory framework that provides for protection of paleontological resources and become familiar with diagnostic characteristics of the materials with the potential to be encountered.

    2) A qualified paleontologist prepares a paleontological resources management plan (PRMP) to guide the salvage, documentation and repository of unique paleontological resources encountered during construction. The PRMP should adhere to and incorporate the performance standards and practices from the 2010 SVP Standard procedures for the assessment and mitigation of adverse impacts to paleontological resources. If unique paleontological resources are encountered during construction, use a qualified paleontologist to oversee the implementation of the PRMP.

    3) Monitor ground disturbing activities in parent material, with a moderate to high potential to yield unique paleontological resources using a qualified paleontological monitor meeting the standards of SVP or BLM to determine if unique paleontological resources

are encountered during such activities, consistent with the specified or comparable protocols.

4) Identify where ground disturbance is proposed in a geologic unit having the potential for containing fossils and specify the need for a paleontological monitor to be present during ground disturbance in these areas.

d) Avoid routes and project designs that would permanently alter unique geological features.

e) Salvage and document adversely affected resources sufficient to support ongoing scientific research and education.

f) Significant recovered fossils should be prepared to the point of curation, identified by qualified experts, listed in a database to facilitate analysis, and deposited in a designated paleontological curation facility.

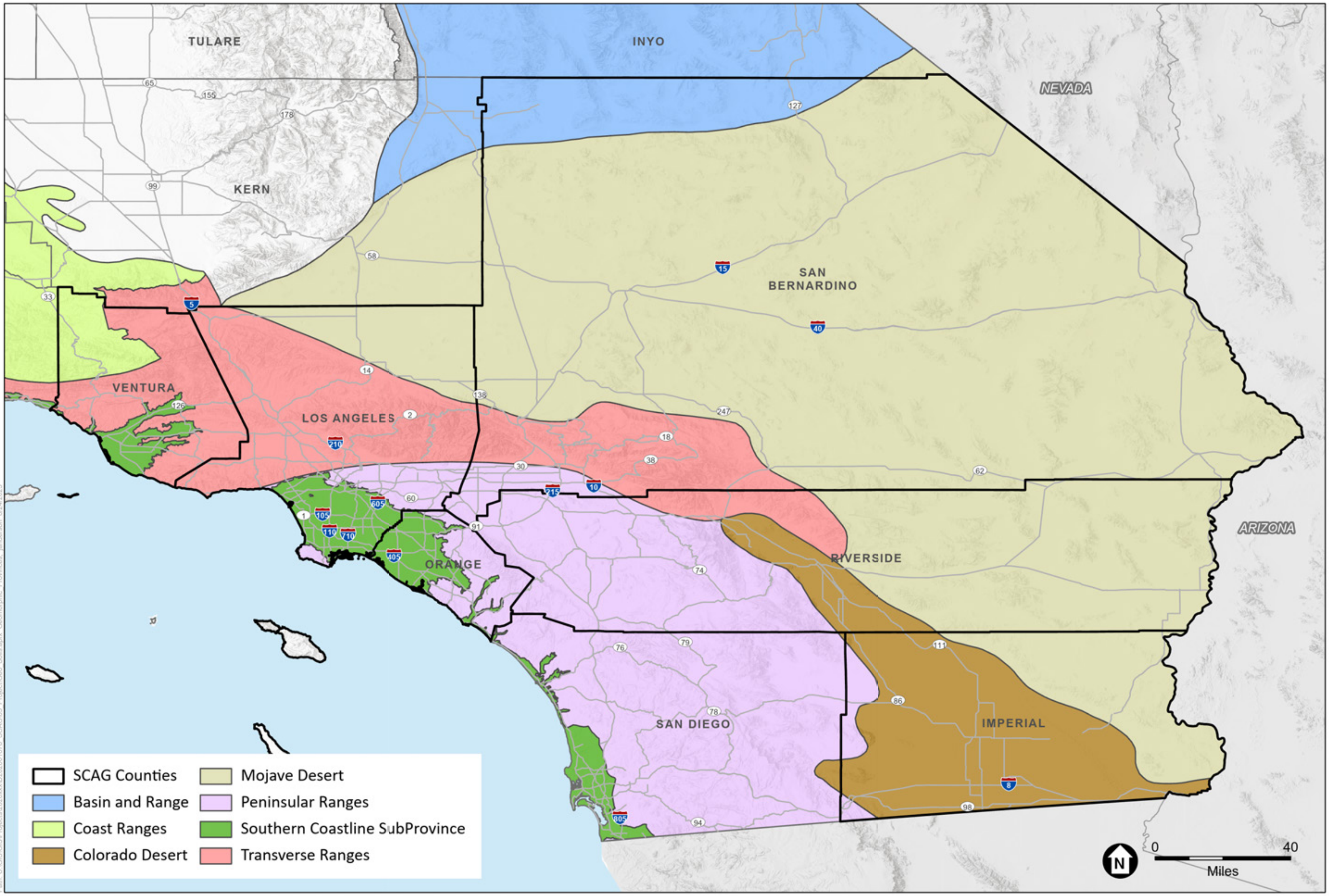
g) Following the conclusion of the paleontological monitoring, the qualified paleontologist should prepare a report stating that the paleontological monitoring requirement has been fulfilled and summarize the results of any paleontological finds. The report should be submitted to the lead CEQA and the repository curating the collected artifacts and should document the methods and results of all work completed under the PRMP, including treatment of paleontological materials, results of specimen processing, analysis, and research, and final curation arrangements.

LEVEL OF SIGNIFICANCE AFTER MITIGATION

As previously discussed, the Plan's Regional Planning Policies and Implementation Strategies (see Chapter 2, *Project Description*, and Section 3.0, *Introduction to the Analysis*), compliance with existing laws and regulations would reduce impacts, but given the regional scale of the analysis in this 2024 PEIR, it is not possible or feasible to determine if all impacts would be fully mitigated. Therefore, this 2024 PEIR identifies SCAG and project-level mitigation measures. At the project level, lead agencies can and should consider the identified project-level mitigation measures during subsequent review of transportation and land use projects as appropriate and feasible. While the mitigation measures will reduce the impacts related to paleontological resources, due to the regional nature of the analysis, unknown site conditions and project-specific details, and SCAG's lack of land use authority over individual projects, SCAG finds that the impact could be ***significant and unavoidable*** even with mitigation.

CUMULATIVE IMPACTS

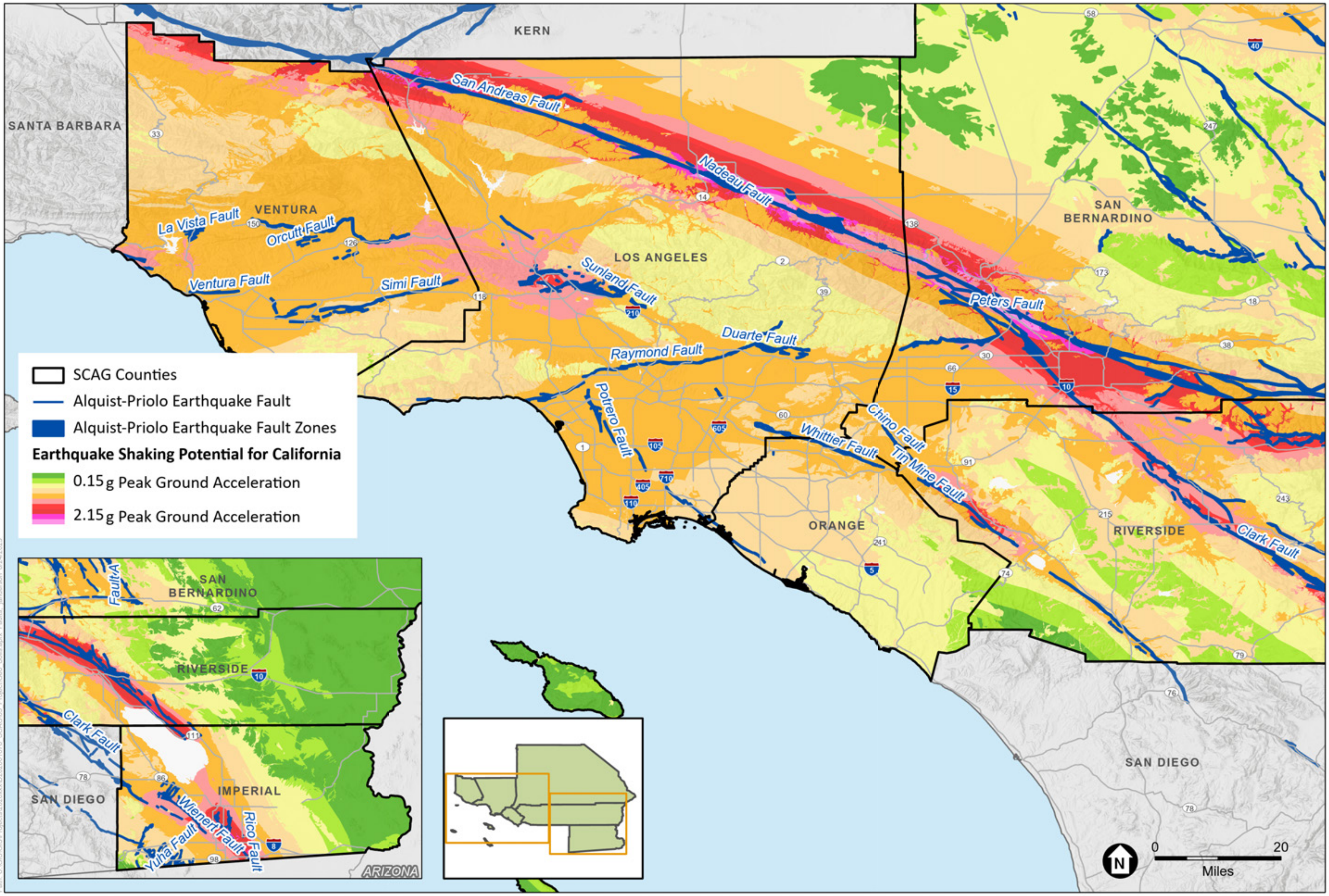
Connect SoCal 2024 is a regional-scale Plan comprised of policies and strategies, a regional growth forecast and land use pattern, and individual projects and investments. At this regional-scale, a cumulative or related project to the Plan is another regional-scale plan (such as Air Quality Management Plans within the region) and similar regional plans for adjacent regions. Because the Plan, in and of itself, would result in significant adverse environmental impacts with respect to geology, soils, and paleontological resources, these impacts would add to the environmental impacts of other cumulative or related projects. Mitigation measures that reduce the Plan's impacts would similarly reduce the Plan's contribution to cumulative impacts.



SOURCE: CGS, 2015, 2018

Connect SoCal 2024 PEIR

Map 3.7-1
Geomorphic Provinces

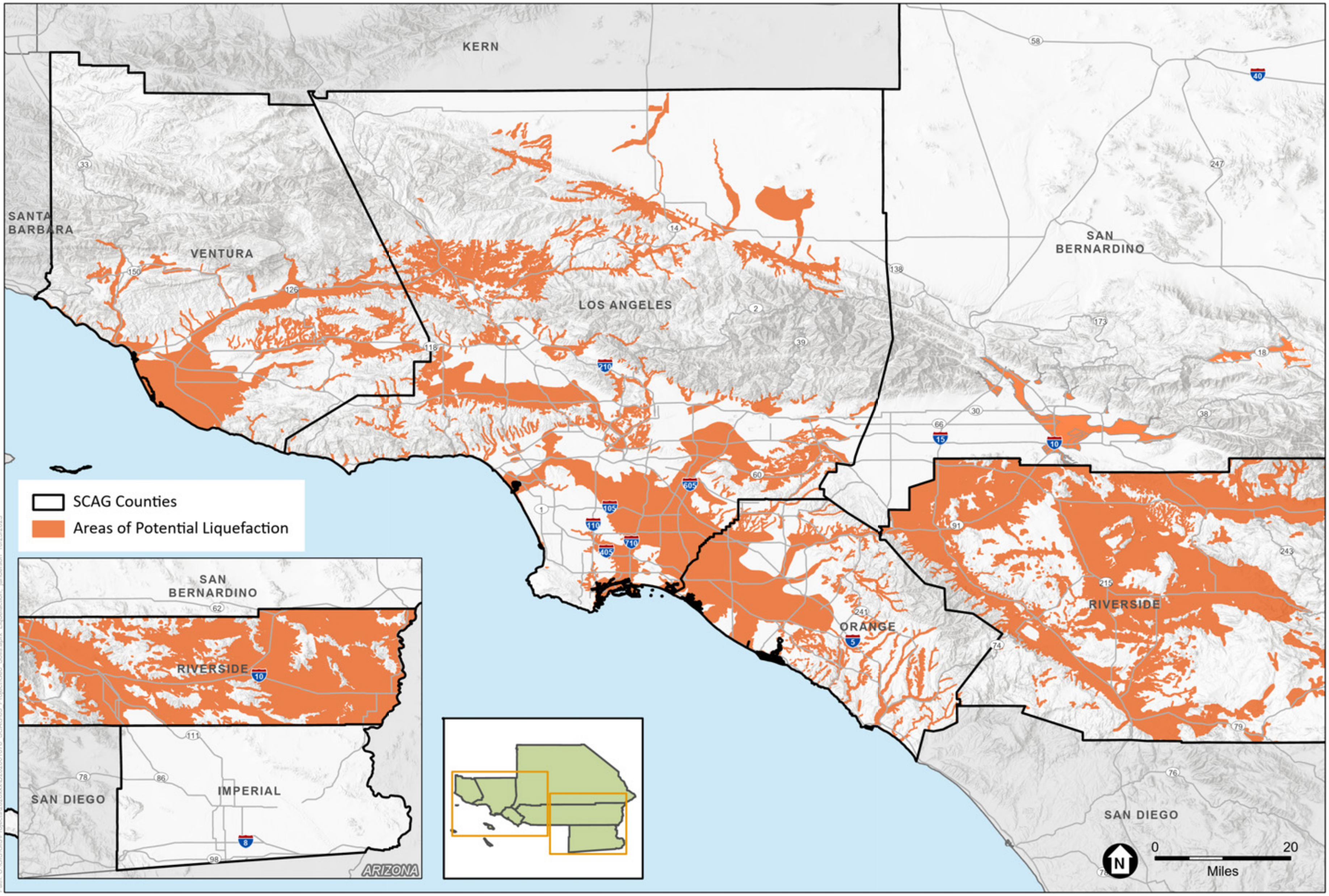


SOURCE: CGS, 2016; USGS, 2023

Connect SoCal 2024 PEIR

Map 3.7-2
Alquist-Priolo Earthquake Fault Zones and Areas of Probabilistic Ground Acceleration

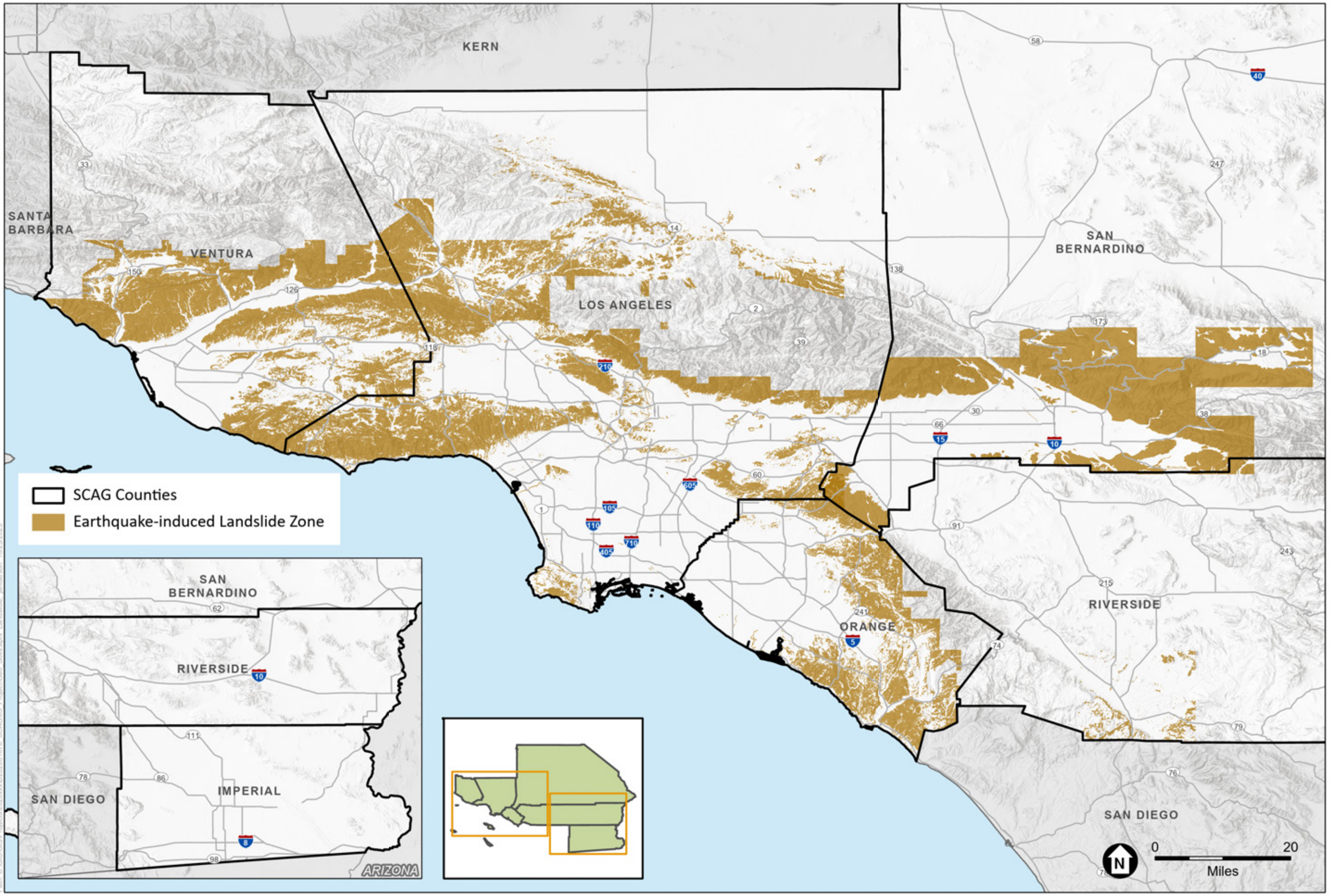
SCAG



SOURCE: : CGS, 2022; Riverside County, 2019; County of San Bernardino LUS, 2016
NOTE: No data available for Imperial County. Partial data available for San Bernardino County.

Connect SoCal 2024 PEIR

Map 3.7-3
Areas of Potential Liquefaction



SOURCE: CGS, 2017; County of San Bernardino LUS, 2016
NOTE: No data available for Imperial County. Partial data available for San Bernardino County.

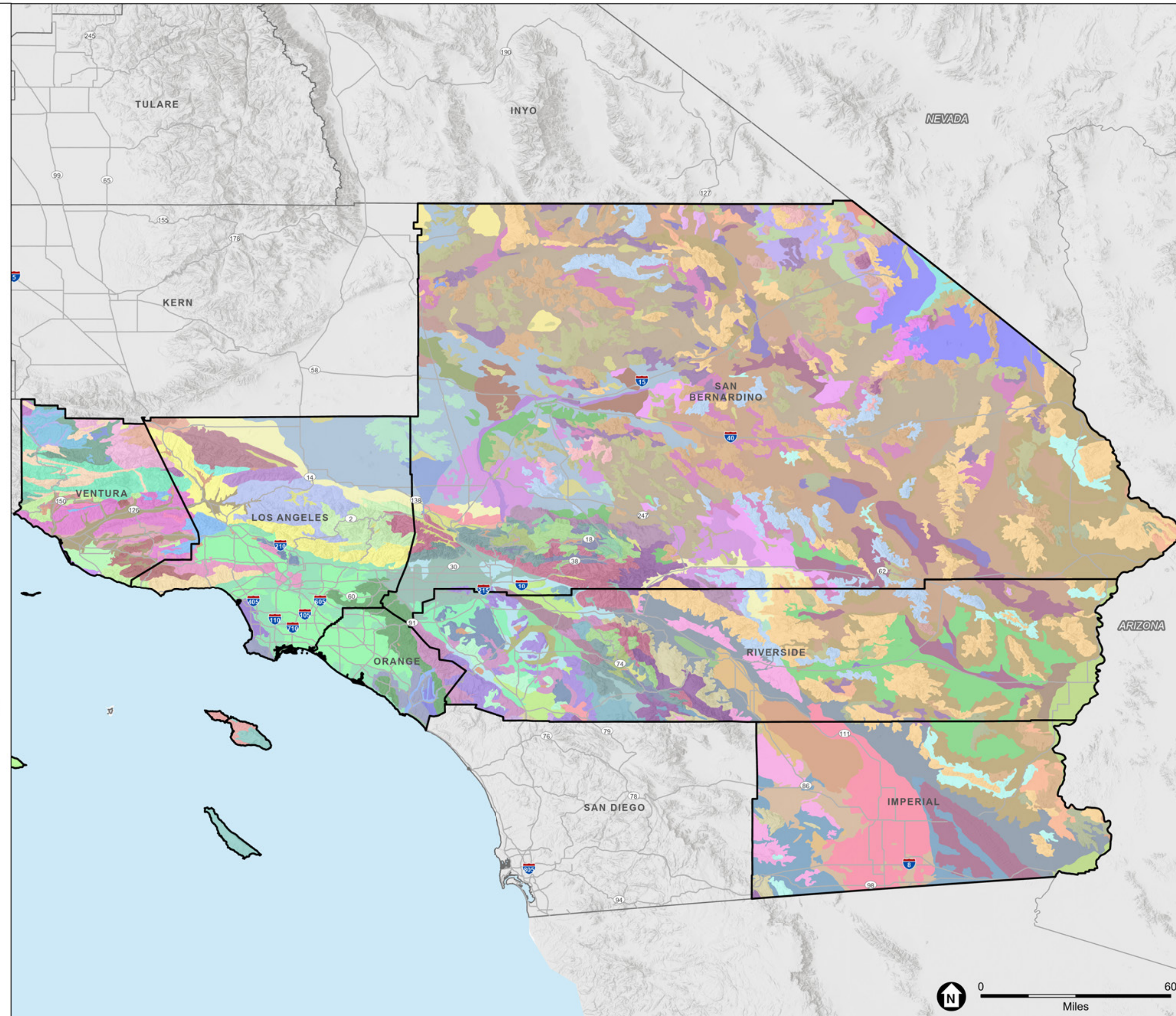
Connect SoCal 2024 PEIR

Map 3.7-4
Areas of Potential Landslides

SCAG

INTENTIONALLY BLANK

- SCAG Counties
- Bluepoint-Arizo (s1123)
- Cajon-Arizo (s1143)
- Cajon-Bitterwater-Bitter-Badland (s1128)
- Dedas-Cave-Canutio-Armpup-Arizo (s5595)
- Dune land-Cajon (s1135)
- Esro (s560)
- Gaviota-Cieneba-Capistrano-Caperton (s1055)
- Glencarb-Cave-Bluepoint (s1145)
- Indio-Gilman-Coachella (s992)
- Kilmer-Beam-Badland (s932)
- Las Flores-Antioch (s1019)
- Los Gatos-Gamboa (s936)
- Mahogan-Glean (s938)
- Manet-Cajon (s1037)
- Marpa-Hilt-Arrastre (s935)
- Millsholm-Millerton-Lodo (s933)
- Milpitas-Concepcion-Baywood (s917)
- Modjeska family-Coarsegold-Aramburu variant (s934)
- Myoma-Carsitas-Carrizo (s991)
- Nebona-Mirage-Joshua-Cajon (s1007)
- Neuralia-Garlock-Cajon-Alko (s769)
- Nickel-Bitter-Arizo (s1142)
- Nickel-Blackmount-Arizo (s1124)
- Norob-Halloran-Cajon-Bryman (s1039)
- Oak Glen-Gullied land-Gorman-Gaviota-Cushenbury (s1034)
- Oak Glen-Mottsville variant-Calpine (s1018)
- Oceano-Dune land-Baywood (s904)
- Olete-Modjeska family-Goulding (s1051)
- Pacheco-Hueneme-Camarillo (s910)
- Pacifico-Chirpchatter-Avawatz (s1048)
- Panoza-Kilmer-Hillbrick-Beam (s977)
- Petspring-Lomoine-Armoine (s5675)
- Pismo-Etsel family-Cieneba-Caperton (s1059)
- Playas (s1038)
- Playas (s1138)
- Ramona-Hanford-Greenfield (s1009)
- Ramona-Hanford-Greenfield-Gorgonio (s1004)
- Ramona-Placentia-Linne-Greenfield (s999)
- Randsburg-Muroc (s770)
- Rillito-Gunsight (s1140)
- Rock outcrop (s1131)
- Rock outcrop-Downeyville-Blacktop (s5668)
- Rock outcrop-Gullied land-Bull Trail-Avawatz-Arrastre (s1040)
- Rock outcrop-Gullied land-Garlock-Bull Trail (s1023)
- Rock outcrop-Hi Vista-Calvista-Cajon (s1031)
- Rock outcrop-Las Posas (s1012)
- Rock outcrop-Lithic Torriorthents (s1021)
- Rock outcrop-Lithic Torriorthents (s1130)
- Rock outcrop-Lithic Xerorthents-Calleguas-Badland (s914)
- Rock outcrop-Lithic Xerorthents-Hambright-Gilroy (s915)
- Rock outcrop-Maymen (s921)
- Rock outcrop-Mexispring (s1077)
- Rock outcrop-Pacifico-Etsel family-Cieneba (s1052)
- Rock outcrop-Pacifico-Modjeska family (s1049)
- Rock outcrop-Petspring-Lomoine-Armoine (s1139)
- Rock outcrop-Rillito-Beeline-Badland (s995)
- Rosamond variant-Rosamond-Playas-Gila-Cajon variant-Cajon (s768)
- Rositas-Beeline-Badland (s1129)
- Rositas-Carrizo (s1137)
- Rositas-Dune land-Cajon (s1025)
- Rositas-Dune land-Carsitas (s1136)
- Rositas-Orita-Carrizo-Aco (s1041)
- Rositas-Orita-Carrizo-Aco (s994)
- Rositas-Pompeii-Gunsight-Carrizo-Ajo (s5589)
- Rositas-Ripley-Indio-Gilman (s275)
- Salt flats-Bunkerhill (s1081)
- San Andreas-Arujo-Arnold (s902)
- San Benito-Castaic-Calleguas-Balcom-Badland (s912)
- San Emigdio-Metz-Grangeville (s1005)
- San Miguel-Friant-Exchequer (s1013)
- San Ysidro-Positas-Arbuckle (s895)
- Schenco-Rock outcrop-Laposa (s295)
- Sesame-Rock outcrop-Cieneba (s1010)
- Sespe-Millsholm-Malibu-Lodo-Hambright (s913)
- Shaver-Pacifico-Chirpchatter (s1050)
- Sheephead-Rock outcrop-Bancas (s1016)
- Skyhaven-Rillito-Mead-McCullough-Ireteba-Bluepoint (s1144)
- Sobrante-Exchequer-Cieneba (s1054)
- Sobrante-Lodo (s1057)
- Soper-Calleguas-Bosanko-Alo (s1029)
- Soper-Chesterton (s911)
- Soper-Fontana-Calleguas-Balcom-Anaheim (s1030)
- Springdale-Rock outcrop-Etsel family (s1053)
- St. Thomas-Rock outcrop (s1125)
- St. Thomas-Schenco-Rock outcrop (s1132)
- Stonyford-Rock outcrop-Chilao (s1056)
- Stutzville-Panoche-Metz (s925)
- Tecopa-Rock outcrop-Lithic Torriorthents (s1126)
- Temescal-Las Posas-Cajalco (s1022)
- Todos-Sespe-Lodo (s919)
- Tollhouse-Rock outcrop-Etsel family-Bakeoven (s1058)
- Tollhouse-Rock outcrop-La Posta (s1014)
- Trigger-Rock outcrop-Calvista (s1134)
- Tujunga-Salinas-Elder (s1001)
- Ubehebe-Rodad-Penelas-Entero (s5673)
- Upspring-Sparkhule-Rock outcrop (s1127)
- Urban land-Delhi (s1028)
- Urban land-Lithic Xerorthents-Hambright-Castaic (s1042)
- Urban land-Marina-Chesterton (s1002)
- Urban land-Monserate-Exeter-Arlington (s1003)
- Urban land-Rock outcrop-Millsholm (s1035)
- Urban land-Sorrento-Hanford (s1026)
- Urban land-Tujunga-Soboba-Hanford (s1027)
- Vaiva-Quilotosa-Hyder-Cipriano-Cherioni (s1141)
- Vaiva-Rock outcrop-Quilotosa-Laposa (s1133)
- Vallecitos-Shoba-Rock outcrop-Millsholm-Lithic Xerorthents (s1045)
- Vallecitos-Thirst-Shoba (s1044)
- Villa-Victorville-Riverwash-Cajon (s1008)
- Vint-Imperial-Glenbar-Gilman (s993)
- Vint-Meloland-Indio (s996)
- Vista-Cieneba-Andregg (s899)
- Vista-Fallbrook-Cieneba (s1011)
- Vizcapoint-Rock outcrop-Dune land (s1046)
- Walong-Rock outcrop-Edmundston-Anaverde (s762)
- Wasco-Helendale-Bryman (s1032)
- Wasco-Rosamond-Cajon (s1024)
- Water (s8369)
- Willows-Traver-Domino (s1006)
- Wilshire-Soboba-Oak Glen-Avawatz (s1047)
- Xerofluvents-Oak Glen-Dotta (s937)
- Xerofluvents-Salinas-Pico-Mocho-Metz-Anacapa (s909)
- Xerorthents-Saugus-San Timoteo-Badland (s1036)
- Xerorthents-Thirst-Shoba-Sanclemente-Rock outcrop-Eelpoint (s1043)
- Zamora-Urban land-Ramona (s1033)



SOURCE: NRCS, 2023

Map 3.7-5
General Soil Types

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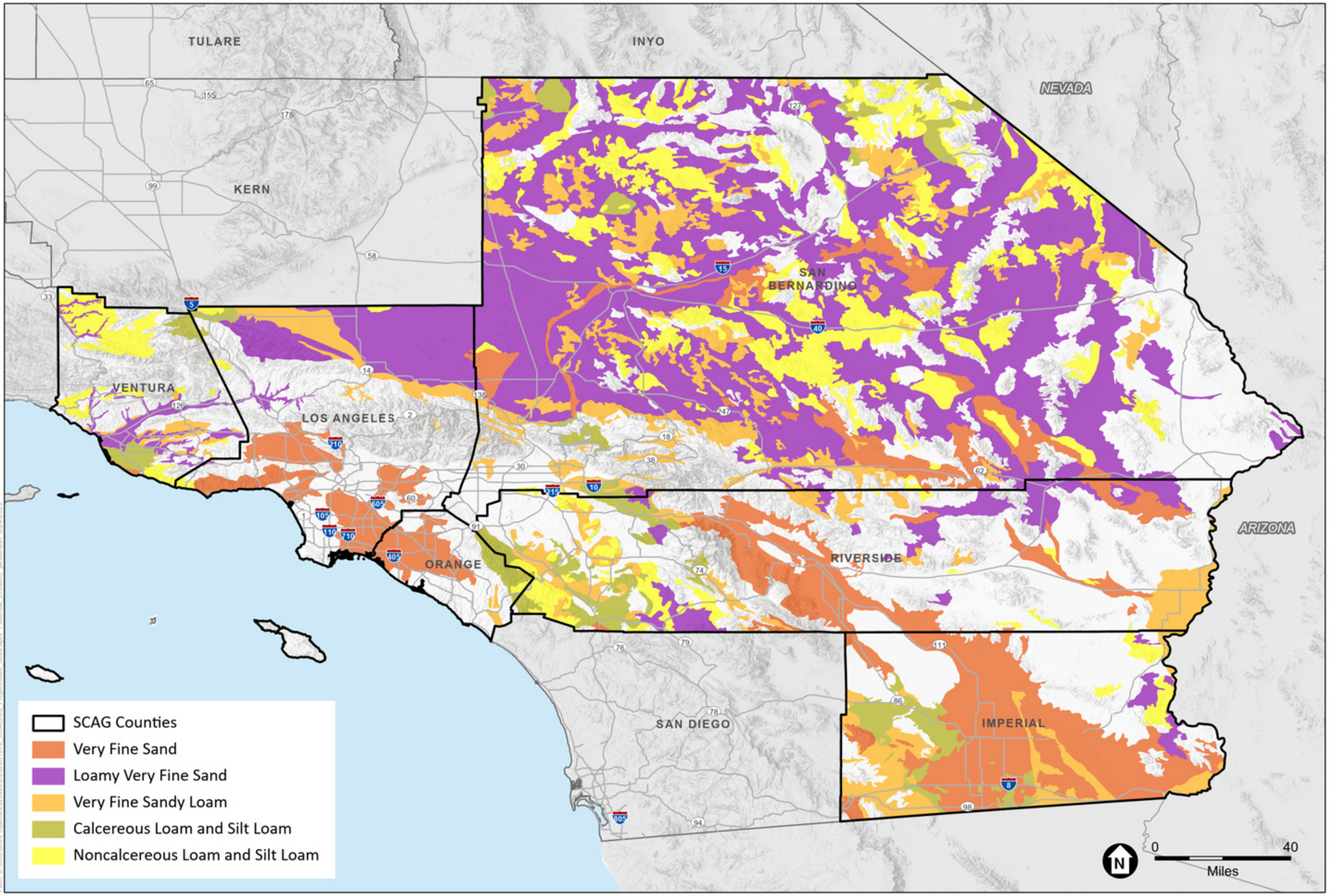

SOURCE: NRCS, 2023

Connect SoCal 2024 PEIR

Map 3.7-6
Soils with Moderate to High Erosion Potential

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