III.4 GEOLOGY AND SOILS

This section describes federal and state regulation of soils and geology, including regional topography, geology, geologic processes, seismicity, and soils, specifically as it relates to the Desert Renewable Energy Conservation Plan (DRECP or Plan). Appendix R1.4 includes 10 maps and 3 tables that support this chapter. The maps illustrate soil textures within the Plan Area's ecoregion subareas, and the tables present data, expressed in acres, for the surficial geology and soil textures in the Plan Area, as well as for soil textures within Development Focus Areas (DFAs) for each Plan alternative.

III.4.1 Regulatory Setting

III.4.1.1 Federal

Federal Land Policy and Management Act

The Federal Land Policy and Management Act (FLPMA) establishes policy and goals for the Bureau of Land Management's (BLM) administration of public lands. The intent of FLPMA is to protect and administer public lands within a multiple-use, sustained-yield program that maintains environmental quality. Its greatest areas of protection are scientific, scenic, historical, ecological, environmental, air and atmospheric, water resources, and archaeological resources. Under FLPMA, BLM is further charged with protecting life and safety from natural hazards.

Clean Water Act

The Clean Water Act (CWA) requires states to set standards to protect water quality by requiring the all construction sites larger than one acre obtain a National Pollution Discharge Elimination System (NPDES) permit prepared through a site-specific Storm Water Pollution Prevention Plan (SWPPP). Stormwater runoff from construction may contain large loads of dissolved and undissolved organic matter, suspended sediment, and pollutant chemicals in construction site soils – all of which can affect water quality. An SWPPP must include a site description (including a map that identifies sources of stormwater discharges on the site), anticipated drainage patterns after major grading, and areas where major structural and nonstructural measures will be employed including surface waters, wetlands, sediment deposition areas, and discharge points to surface waters.

III.4.1.2 State

California Land Conservation Act of 1965

The California Land Conservation Act of 1965, commonly known as the Williamson Act, was enacted to preserve California's prime agricultural lands from urbanization. The Williamson Act has been amended several times to allow its use for purposes other than protection of prime agricultural lands; local governments may now enter into contracts with private landowners to dedicate specific parcels of land to open space.

Alquist–Priolo Earthquake Fault Zoning Act of 1972, Public Resources Code (PRC) Section 2621–2630

This act's main purpose is to prevent construction of buildings used for human occupancy on the surface trace of active faults. Before issuing building permits, cities and counties must require a geologic investigation to ensure that proposed buildings are not constructed across active faults. Proposed building sites must be evaluated by a licensed geologist.

California Building Code 2010 Edition

The California Building Code (2010 Edition) contains a series of construction project standards: design and construction, including grading and erosion control. The 2010 edition is based on the 2009 International Building Code (excluding Appendix Chapter 1) published by the International Code Council, with the addition of more extensive seismic structural standards. The California Building Code (Chapter 16) contains definitions of the seismic sources and procedures used to calculate seismic forces on structures.

III.4.1.3 County Plans

Renewable energy facilities constructed within the Plan Area would be required to comply with all county building codes and acquire all needed building and grading permits. The following General Plan elements pertain to geology and soils issues within the Plan Area.

Imperial County General Plan—Seismic and Public Safety Element

The Seismic and Public Safety Element of the Imperial County General Plan contains goals and policies to minimize the risks from natural and human-made hazards, including seismic and geological hazards and flood hazards (Imperial County 1993).

Inyo County General Plan—Safety Element

The Safety Element of the Inyo County General Plan establishes policies and programs to minimize risks to the community from seismic, geologic, flood, and fire hazards (Inyo County 2001).

Kern County General Plan—Safety Element

The Safety Element of the Kern County General Plan contains goals and policies to minimize risks from geologic, fire, flood safety hazard areas, and hazardous materials (Kern County 2009).

Los Angeles County General Plan—Safety Element

The Safety Element of the Los Angeles County Draft General Plan contains goals and policies to minimize risks from seismic and geotechnical hazards, flood and inundation hazards, and fire hazards. The purpose of the Safety Element is to reduce the potential risk of death, injuries, and economic damage from natural and human-caused hazards (Los Angeles County 2012).

Riverside County General Plan—Safety Element

The primary objective of the Riverside County General Plan Safety Element is to reduce death, injuries, property damage, and economic and social impact from hazards. The Safety Element (1) develops a framework by which safety considerations are introduced into the land use planning process; (2) facilitates the identification and mitigation of hazards for new development, strengthening existing codes, project review, and permitting processes; (3) presents policies directed at identifying and reducing hazards in existing development; and (4) strengthens earthquake, flood, inundation, and wild land fire preparedness planning and post-disaster reconstruction policies (Riverside County 2008).

San Bernardino County General Plan—Safety Element

The purpose of the Safety Element of the San Bernardino County General Plan is to reduce the potential risk of death, injuries, property damage, and economic and social dislocation from fires, floods, earthquakes, landslides, and other hazards. The Safety Element addresses risks associated with (1) seismically induced surface rupture, ground shaking, ground failure, seiche, and dam failure; (2) slope instability leading to mudslides and landslides; (3) subsidence, liquefaction, and other seismic hazards identified on seismic hazard maps; (4) other known geologic hazards; (5) flooding; and (6) wild land and urban fires (San Bernardino County 2011).

San Diego County General Plan—Safety Element

The purpose of the San Diego County General Plan Safety Element is to include safety considerations in planning and decision-making processes by establishing future development policies that minimize the risk of personal injury, loss of life, property damage, and environmental damage from both natural and human-caused hazards. These hazards include wildfires, geological and seismic hazards, flooding, hazardous materials, law enforcement actions, and airport hazards (San Diego County 2011).

III.4.2 Geology and Soils within the Plan Area

Surficial geology, geologic processes, and soil conditions and types could all either affect or be affected by renewable energy facility siting in the Plan Area. The majority of the Plan Area covers the Mojave and Sonoran desert regions of southeastern California, with areas both within and east of the Sierra Nevada mountain range. The Mojave and Sonoran deserts are made up of short, scattered mountain ranges within large desert plains. These inter-mountain regions include playas and basins that form terminal dry lakes, alluvial fans, major dune systems, and broad washes called bajadas.

III.4.2.1 Geomorphology and Surficial Geology

Geomorphology concerns the landforms and relief patterns that make up the earth's surface. Small portions of the Plan Area extend into the mountains west and northwest, but outside of, the Plan Area: the San Bernardino and Western Transverse mountain ranges (west of the Plan Area)and the Sierra Nevada mountain range (northwest of the Plan Area). Overall, about 97% of the Plan Area is in the Mojave and Sonoran desert regions of California. 71% of the Plan Area is in the Mojave Desert, and 26% is in the Sonoran Desert. This discussion covers the geomorphology of both desert regions in the Plan Area.

The Mojave Desert is bounded on the west by the Sierra Nevada and on the south by the San Bernardino, Little San Bernardino, and San Gabriel mountain ranges. Within the Plan Area, the Sonoran Desert is bounded on the west by the Peninsular Ranges and on the east by the Colorado River. The large mountain ranges create the rain-shadow effect that in turn creates these arid desert regions. The geomorphology of the Mojave and Sonoran desert regions is dominated by short, isolated mountain ranges within desert plains. Major land-forms include mountains, plateaus, alluvial fans, playas, basins, and dunes. Basins and ranges are common in the Plan Area.

There are at least 65 named mountain ranges in the Plan Area. Many of these mountain ranges have alluvial fans, which are the fan-shaped landforms that form around the base of mountains (Harden 2004). Where large alluvial fans join together, a broad gentle alluvial plain is formed, creating a geomorphic feature known as a bajada. The intermountain areas are characterized by numerous playas and basins, which form dry lakes known commonly as playas.

There are 23 dry lakes within the Plan Area (CEC 2012). These dry lakebeds, which provide wildlife habitat and sand sources for sand transport corridors and dune systems, include:

- Rosamond Dry Lake
- Silurian Lake
- Cuddeback Lake
- Bristol Lake
- Melville Lake
- Coyote Lake
- Danby Lake
- Silver Dry Lake
- Palen Lake
- Ford Dry Lake
- China Lake
- Bagdad Lake
- Harper Dry Lake
- Twentynine Palms
- Dale Lake
- Searles Lake
- Cronese Lake
- Kelso Wash/Dry Lake
- Cadiz Lake
- Leach Lake
- Mesquite Lake
- Lavic Lake
- Bicycle Lake

There are approximately 16 named sand dune systems in the Plan Area (CEC 2012). Among the largest are the Algodones Dunes, located in the Sonoran Desert south of the Salton Sea in Imperial County. The public uses the Kelso Dunes and the Mojave National Preserve for hiking and recreation. The 16 major dune systems in the Plan Area include:

- Olancha Dunes
- Death Valley (Mesquite) Dunes
- Dumont Dunes
- Cadiz Dunes
- Algodones Dunes/East Mesa
- Danby Dunes
- Means Dunes
- Rice Valley Dunes
- Panamint Dunes
- Ibex-Saratoga Dunes
- Kelso Dunes
- Palen Sand Dunes
- Chuckwalla Valley Dunes
- Little Dumont Dunes
- Ballarat Dunes
- Salton Sea Dunes

Surficial geology concerns the unconsolidated geological surface materials that lie above bedrock; it is an important factor in soil formation and in the type and distribution of local desert vegetation. Figure III.4-1, Surficial Geology, presents the surficial geologic units within the Plan Area. Table R1.4-1, Surficial Geology in the Plan

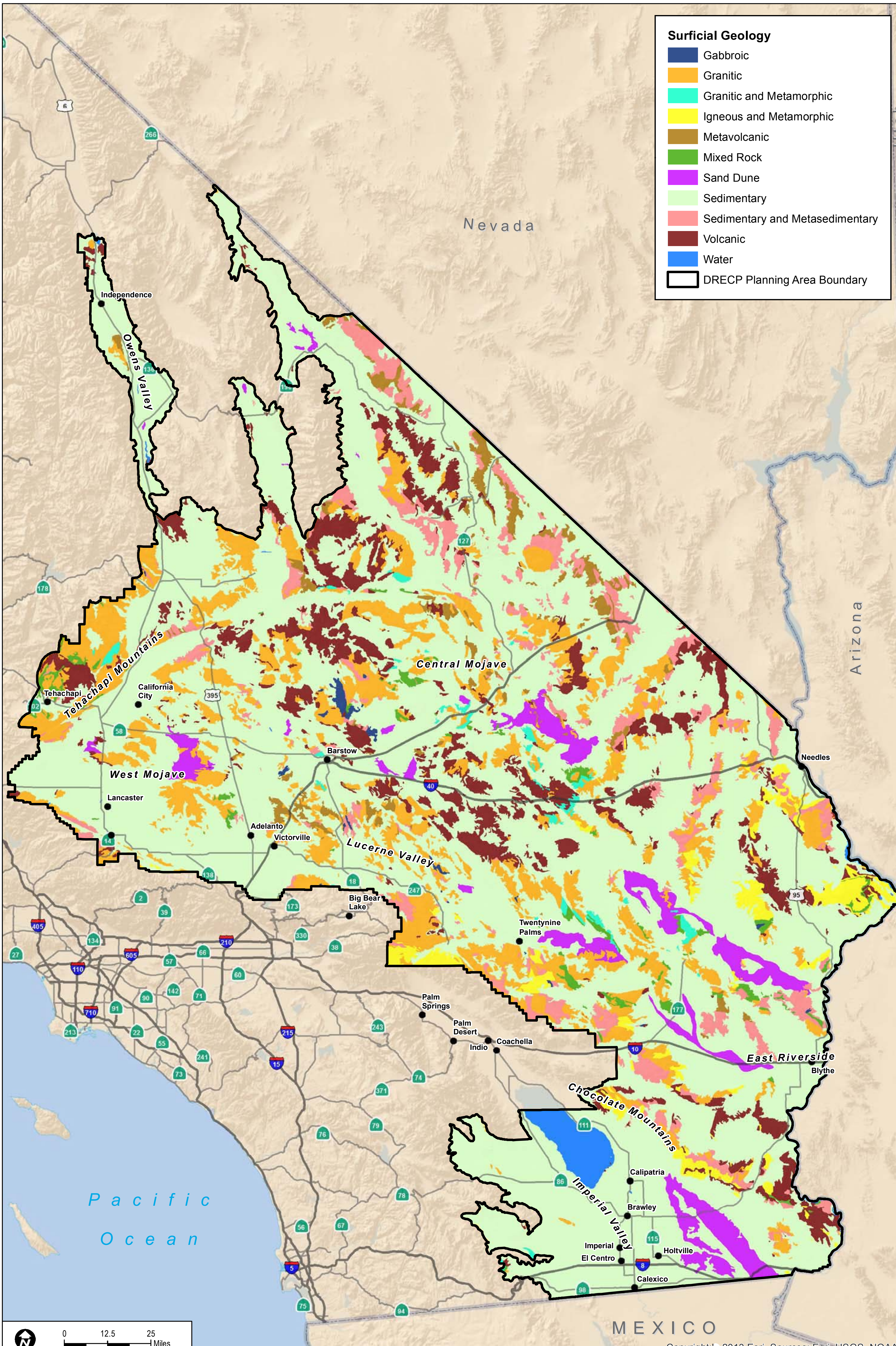
Area (in Appendix R1), defines the acreage of the geologic formations across the Plan Area. The table lists 39 separate geologic units, but most would not affect development of renewable energy projects. For this analysis, the most prevalent and important geologic units are described below:

1. The majority of the ground surface of the Plan Area (over 60%) is composed of alluvium, which is unconsolidated sediment deposited by flowing water in streams or sheets. Subsequent environmental processes have variably consolidated these sediments. Alluvium, shown as sedimentary rock type in Figure III.4-1, Surficial Geology, is more common in the flatter regions of the Plan Area, and less common in more mountainous areas.
2. Young volcanic rocks (where volcanoes were active within the last 2.5 million years) make up about 143,000 acres (6% of the Plan Area). These relatively young volcanic features include:
    a. Cima, Amboy-Pisgah, and Turtle Mountain features in San Bernardino County.
    b. Pinto Basin–Salton Creek in Riverside County.
    c. Obsidian Buttes in Imperial County (Harden 2004).
3. Sand dunes make up relatively small portions of the Plan Area but still account for substantial acreage. Sand dune deposits comprise about 3% (approximately 707,000 acres) of the Plan Area.
4. Landslide deposits within the Plan Area are small. The Plan Area includes just over 4,000 acres (less than 0.02%) of landslide materials.

III.4.2.1.1 Physiography and Geologic Setting

III.4.2.1.1.1 Cadiz Valley and Chocolate Mountain Ecoregion Subarea

The Cadiz Valley and Chocolate Mountains ecoregion subarea occupies the northeastern portion of the Colorado Desert and extends from the Colorado River in the east to the Eagle Mountains, Coxcomb Mountains, and Bullion Mountains in the west, and from the Chocolate Mountains and Orocopia Mountains in the south to the Whipple Mountains, Vidal Valley, Turtle Mountains, Cadiz Valley, and Old Woman Mountains in the north.



Sources: ESRI (2014); CEC (2013); BLM (2013); CDFW (2013); USFWS (2013); CA Geological Survey (2011)

FIGURE III.4-1

Surficial Geology

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The geologic structure in this ecoregion subarea is complex and reflects the regional juxtaposition of large-scale tectonic forces from the transform faulting and rifting to the south along the San Andreas Fault Zone and the crustal extension to the north in the Basin and Range province. The southern mountain ranges (e.g., Chocolate Mountains and Chuckwalla Mountains), therefore, have a general northwest–southeast alignment, parallel to the San Andreas Fault Zone, while the northern mountains (e.g., Iron Mountains and McCoy Mountains) trend more north–south in keeping with the general structural trend of the Basin and Range province. The oldest rocks in the ecoregion subarea are Precambrian metamorphic rocks in the core of the Chocolate Mountains, Chuckwalla Mountains, and Big Maria Mountains.

These rocks were intruded into and altered by Mesozoic plutonic rocks. In the Chocolate Mountains, surprisingly young (~23 Ma [Ma denotes *million years before the present*]) plutonic rocks have also contributed to alteration of the older rocks in this area. Extensive sequences of volcanic rocks of roughly the same age occur in the eastern Chocolate Mountains, Palo Verde Mountains, and Black Hills. There are also younger Miocene fanglomerates and Pliocene nonmarine sedimentary rocks in these southern mountain ranges, as well as in the southeastern Whipple Mountains on the north side of Vidal Valley. The geology of the Palen Mountains and McCoy Mountains is unusual for the California desert region since it contains a thick sequence of late Mesozoic (~120 to 65 Ma) nonmarine sedimentary rocks (the McCoy Formation). The broad valleys in this ecoregion subarea have been substantially filled with Quaternary (~2.5 Ma to recent) fluvial, alluvial fan, and lacustrine deposits from adjacent mountain ranges. Several periods of deposition, uplift, and erosion are recorded in these deposits, which can be differentiated between older Quaternary alluvial fan sequences and those still being formed today. As with other desert areas, there are several dry playa lakes in the valley floors.

III.4.2.1.1.2 Imperial Borrego Valley Ecoregion Subarea

The Imperial Borrego Valley ecoregion subarea encompasses the majority of the Salton Basin between the Chocolate Mountains and San Andreas Fault Zone in the east and the eastern flanks of the Peninsular Ranges in the west. The Salton Sea forms a substantial part of the northern portion of this ecoregion subarea, while the Anza-Borrego Desert State Park and the Ocotillo Wells State Vehicular Recreation Park encompass large areas of the western portion.

The central portion of this ecoregion subarea is characterized by low-relief topography associated with the Pleistocene to Holocene (~37 to 0.5 thousand years before the present) Lake Cahuilla (see below). In the east lie the Algodones Dune field; in the west the Borrego Badlands, Carrizo and Vallecito Badlands, and Yuha Basin are separated by the Vallecito and Coyote Mountains, respectively. These western valleys contain deformed sequences of late Miocene (~6 Ma) through middle Pleistocene (~0.7 Ma) marine to nonmarine sedimentary rocks. These rocks record the opening and flooding of the proto-Gulf of California during the late Miocene (~7 to 6 Ma), the initiation and westward progradation of the ancestral Colorado River Delta during the Pliocene (~4.5 to 2.5 Ma), and the cyclical formation and desiccation of large perennial lakes formed by periodic changes in the flow of the Colorado River during the Pleistocene and Holocene (~2.5 Ma to 0.4 thousand years before the present). Today, as much as 2,000 square miles of the ecoregion subarea lie below sea level, protected from marine waters of the modern Gulf of California by the sediment "dam" formed by the Colorado River Delta.

III.4.2.1.1.3 Kingston and Funeral Mountain Ecoregion Subarea

The Kingston and Funeral Mountains ecoregion subarea encompasses the northeastern portion of the Plan Area and is a western extension of the Basin and Range province into California. It extends from the California-Nevada border in the east to Amargosa Mountains, Silurian Valley, and Old Dad Mountains in the west, and from Ivanpah Valley and the Kelso Dune Field in the south to the Grapevine Mountains and Funeral Mountains in the north. As a western extension of the Basin and Range province, this ecoregion subarea is characterized by a series of northwest-trending mountain ranges and intervening valleys, each bounded by frontal faults that have uplifted the ranges and downdropped the basins. This general geologic structure also continues into the adjacent Panamint and Death Valley ecoregion subarea and the Mojave and Silurian Valley ecoregion subarea.

The geology of the mountain ranges in this ecoregion subarea is somewhat more complex than in other parts of the Plan Area. This area includes very ancient, marine sedimentary rock units of Proterozoic (~>1000 Ma) and Paleozoic (~540 to 250 Ma) age that have not been subjected to the intense metamorphic conditions that have altered similar aged rocks farther west in the Mojave Desert. The geologic history of the valley areas, however, is similar to that of other areas in the Mojave Desert and primarily reflects internal drainage systems with streams and alluvial fans flowing off uplands to fill adjacent basins. As is often the case, these internal drainage systems culminated during the Pleistocene, forming local pluvial lakes that in some cases became interconnected, especially along the Amargosa River drainage.

III.4.2.1.1.4 Mojave and Silurian Valley Ecoregion Subarea

The Mojave and Silurian Valley ecoregion subarea encompasses much of the central portion of the Mojave Desert from Silurian Valley and Soda Valley in the east to the Rand Mountains, Gravel Hills, and Calico Mountains in the west, and from the Manix Basin in the south to Pilot Knob Valley, the Granite Mountains, and the Avawatz Mountains in the north. Topographically, the region is similar to the adjacent Kingston and Funeral Mountains ecoregion subarea.

The ecoregion subarea is characterized by a series of generally northwest-trending mountain ranges and intervening valleys, each bounded by frontal faults that have uplifted the ranges and downdropped the basins. However, east–west trending mountain ranges to the north (e.g., Rand Mountains, Granite Mountains, and Avawatz Mountains) cut across this general northwest structural grain and are largely the result of tectonic forces from the Garlock Fault.

III.4.2.1.1.5 Owens River Valley Ecoregion Subarea

The Owens River Valley ecoregion subarea is the smallest ecoregion subarea in the Plan Area and is confined to the floor of Owens Valley between Little Lake on the south and Tinemaha Reservoir on the north. Owens River traverses the valley from north to south and flows from its headwaters in the Sierra Nevada Mountains and Inyo Mountains into Owens Lake. Since 1913 a majority of this flow has been diverted to the Los Angeles Basin via the Los Angeles Aqueduct. Owens Valley lies in the western part of the Basin and Range province and is a downdropped basin between the White and Inyo Mountains to the east and the Sierra Nevada Mountains to the west.

The Owens Valley floor itself is relatively flat for much of its length and width, but is punctuated in places by resistant igneous rocks of both plutonic and volcanic origin. At the Alabama Hills in the center of the valley, the Central Owens Valley Fault has offset Cretaceous-age plutonic rocks of the Sierra Nevada Batholith and older Mesozoic metasedimentary rocks. Farther north in the valley are a series of well-preserved Pleistocene cinder cones and volcanic flows on either side of the valley floor. Owens Lake occupies the southern portion of Owens Valley and is a mere shadow of its Pleistocene, pluvial self. Younger and older Pleistocene lacustrine deposits in this area attest to the former size of Lake Owens, which at it maximum inundation was over 300 feet deep. There are extensive accumulations of Pleistocene and Holocene volcanic rocks in the Coso Range east of Owens Valley.

III.4.2.1.1.6 Panamint Death Valley Ecoregion Subarea

The Panamint Death Valley ecoregion subarea encompasses the western corner of the Basin and Range province and consists of a north–south trending series of down-dropped basins (e.g., Death Valley and Panamint Valley) separated by block-faulted mountain ranges (e.g., the Amargosa Range, Panamint Range, and Argus Mountains). For the most part, the uplifted mountain ranges are excluded from this ecoregion subarea, which primarily includes only the elongate valley floors of Death Valley, Panamint Valley, and Searles Valley.

The major uplands regions are to the south and include the Owls Head Mountains, Quail Mountains, Slate Range, Spangler Hills, and El Paso Mountains.

The general east–west trending Garlock Fault controls the topography along the southern boundary of this ecoregion subarea. The oldest rocks are erosional remnants of Precambrian metamorphic rocks in the southern Panamint Range. There are limited amounts of Paleozoic marine sedimentary rocks on the northern part of the Slate Range and in the eastern portion of the El Paso Mountains. Plutonic igneous rocks of Mesozoic age are widely exposed in the Owls Head Mountains, the Slate Range, the southern Argus Range, and the Spangler Hills. There are localized remnants of Mesozoic roof pendants, altered by intrusion of the younger Mesozoic plutonic rocks, in the southern Panamint Range. Cenozoic volcanic rocks are concentrated over a broad area in the Quail Mountains and the southern Panamint Range, while Cenozoic sedimentary rocks have a more patchy distribution, primarily along the Garlock Fault. Paleocene-age rocks of the Goler Formation are confined to the El Paso Mountains.

Much younger Quaternary-age sediments fill the broad basins of Searles Valley, Panamint Valley, and Death Valley, and there are several dry lake beds in the floors of these valleys today.

III.4.2.1.1.7 Pinto Lucerne Valley and Eastern Slopes Ecoregion Subarea

The Pinto Lucerne Valley and Eastern Slopes ecoregion subarea encompasses the southern portion of the Mojave Desert from the Bullion Mountains in the east to the Mojave River in the west, and from the San Bernardino and Cottonwood Mountains in the south to the Newberry Mountains and Stoddard Valley in the north. The northern part of this ecoregion subarea conforms geologically with other parts of the western Mojave Desert, so consists of a series of northwest-trending mountain ranges bounded by parallel striking faults. In contrast, the southern portion of this ecoregion subarea has more in common with the transverse ranges that begin in the Santa Ynez Mountains in Santa Barbara County and extend eastward as a series of east–west trending mountain ranges that terminate in the Little San Bernardino Mountains, Pinto Mountains, and Eagle Mountains.

The geology of these transverse-trending mountains is dominated by Mesozoic plutonic rocks and well-metamorphosed Precambrian rocks. The mountain ranges in the north also expose large masses of Mesozoic plutonic rocks. The smaller mountain ranges and buried peaks at the north end of Apple Valley and Lucerne Valley are notable exceptions; they expose thick sequences of resistant, Mesozoic volcanic rocks. There are similar rocks in the Ord Mountains and Rodman Mountains. There are limited Cenozoic sedimentary rocks in this ecoregion subarea in isolated fault blocks of the Newberry Mountains and along the northern flanks of Stoddard Valley.

Like other ecoregion subareas, there are extensive fluvial and lacustrine deposits of Pleistocene age form deep valley fills in the many large and small valleys. There are especially thick valley fills in Apple Valley, Lucerne Valley, Johnson Valley, and, in the south, Pinto Basin.

III.4.2.1.1.8 Piute Valley and Sacramento Mountains Ecoregion Subarea

The Piute Valley and Sacramento Mountains ecoregion subarea spans the approximate boundary between the Colorado Desert and Mojave Desert. It extends from the Colorado River and Piute Valley in the east to the Turtle Mountains, Old Woman Mountains, and Piute Mountains in the west, and from the Whipple Mountains and Chemehuevi Valley in the south to the Dead Mountains and Piute Valley in the north. Topographically, this ecoregion subarea contains extensive aprons of active alluvial fans that extend from widely separated uplands into the adjacent valleys. The Sacramento Mountains trend northwest–southeast across the ecoregion subarea and create a prominent divide between Chemehuevi Valley to the south and Piute Valley to the north.

The oldest rocks are in the core of the Sacramento Mountains and in the Chemehuevi Mountains to the southeast, and consist of Precambrian metamorphic and igneous rocks that are in close fault contact with much younger Cenozoic-age volcanic rocks. There is an outlier of Mesozoic plutonic rocks in the northern part of the Turtle Mountains. Sedimentary rocks are largely confined to the broad and extensive alluvial fan and fluvial sequences that have been filling low-lying areas of this region since at least early Pleistocene time.

III.4.2.1.1.9 Providence and Bullion Mountains Ecoregion Subarea

The Providence and Bullion Mountains ecoregion subarea encompasses the southeastern portion of the Mojave Desert. It extends from Lanfair Valley and the Old Woman Mountains in the east to the Cady Mountains and Bullion Mountains in the west, and from the Cadiz Valley and Sheep Hole Mountains in the south to the New York Mountains, Providence Mountains, and Bristol Mountains in the north. Topographically, the ecoregion subarea is similar to other areas in the eastern Mojave Desert and contains a series of generally northwest-trending mountain ranges and intervening valleys bounded by frontal faults that have uplifted the ranges and down-dropped the basins. However, there are both several north–south trending mountain ranges (e.g., the Providence Mountains and Old Woman Mountains) and a succession of broad alluvium-filled valleys (e.g., Lanfair Valley, Clipper Valley, Bristol Valley, and Cadiz Valley) in this ecoregion subarea.

There are crystalline basement rocks of Precambrian age, intruded by Mesozoic plutonic rocks, in the cores of the eastern mountain ranges including the Old Woman Mountains, Piute Mountains, Clipper Mountains, and Granite Mountains; mountain ranges in the west are primarily composed of extensive accumulations of Cenozoic volcanic rocks. Examples of these volcanic rocks include Miocene lava flows preserved in the northern Bullion Mountains, as well as very young (late Pleistocene; ~25 ka) lava flows and cinder cones (e.g., Pisgah Crater) in the Lavic Lake Volcanic Field south of Newberry Springs. Cenozoic sedimentary rocks occur sporadically in this ecoregion subarea, with notable exposures in the Cady Mountains. Large playa lake beds (e.g., Bristol Lake and Dale Lake) cover several of the valley floors and represent Ice Age relicts of once-larger Pleistocene pluvial lakes.

III.4.2.1.1.10 West Mojave and Eastern Slopes Ecoregion Subarea

The West Mojave and Eastern Slopes ecoregion subarea encompasses the western portion of the Mojave Desert from the Mojave River west through El Mirage Valley and the Antelope Valley to nearly Quails Lake, and from the San Andreas Fault Zone along the eastern flanks of the San Gabriel Mountains north to the southeastern slopes of the southernmost Sierra Nevada Mountains. It further extends north into Indian Wells Valley around the western end of the El Paso Mountains. The main, western Mojave Desert portion of this ecoregion subarea is characterized by broad expanses of low relief alluvial plains punctuated by isolated buttes, ridges, and hills. These upland areas are mostly composed of non-fossil-bearing Mesozoic-age plutonic igneous rocks (e.g., Antelope Buttes, Rosamond Hill, Soledad Mountain, Bissell Hills, Castle Butte, Shadow Mountains, and Kramer Hills) that represent the weathered "peaks" of a deeply eroded and ancient landscape that has mostly been buried beneath the younger Pleistocene basin filling alluvial and lacustrine deposits.

A series of northwest trending faults has deformed portions of the ancient basement plutonic rocks. To a varying extent, these faults are also responsible for the spotty preservation of a series of middle and late Cenozoic nonmarine sedimentary rock units in areas like Rosamond Hill and the Bissell Hills (Fiss Fanglomerate and Gem Hill Formation), Castle Butte (Tropico Group), and Kramer Hills (Tropico Group). Local faulting is also responsible for the uplift and dissection of Pleistocene older alluvial fan deposits adjacent to the Mojave River drainage, as well as in several inter-basin valleys like Hinkley Valley, Harper Valley, and Fremont Valley. Larger-scale faulting related to the San Andreas Fault Zone and the Garlock Fault is associated with the uplift and dissection of Pleistocene alluvial fans along the flanks of the San Gabriel, Tehachapi, and southern Sierra Nevada mountains.

There are localized playa lake deposits (e.g., Rosamond Dry Lake and Rogers Dry Lake) in low-lying areas away from the mountains; they are Pleistocene and Holocene remnants of much larger pluvial lakes (e.g., Lake Thompson) that characterized the region during the Pleistocene glacial periods. The Mojave River is a prominent element in the eastern portion of this ecoregion subarea and is responsible for depositing a relatively thick sequence of Pleistocene-through-Holocene-age fluvial sediments.

III.4.2.1.2 Geologic Processes

There are three fundamental geomorphic processes that shape the surficial geology of desert systems and the transportation and deposition of substrates (Miller et al. 2009):

1. Aeolian processes describe wind transported materials.
2. Fluvial, alluvial, and lacustrine processes describe water-transported materials.
3. Mass-wasting processes describe gravity-transported materials.

Surficial deposits vary according to several factors related to these depositional processes including particle size, cohesiveness, bulk density, lateral and vertical heterogeneity, and the degree of sorting (Miller et al. 2009). Descriptions of these geomorphic processes and their corresponding deposits follow.

In the Mojave Desert, alluvial fans are formed through flowing water that pushes debris from mountain foothills (Miller et al. 2009). Sand dunes and sheets are formed through aeolian, or wind processes. Playas and valley washes are formed through fluvial, lacustrine, and aeolian processes. Hillslope materials are formed through mass-wasting processes, and wetland deposits are formed through fluvial and aeolian processes. Surficial deposits vary according to several factors including particle size, cohesiveness, bulk density, lateral and vertical heterogeneity, and the degree of sorting (Miller et al. 2009).

Aeolian Processes

The erosion, transport, and deposition of wind-blown sediments shape the desert landscape, affecting desert pavement, sand sheets, and dune systems (BLM 2002[a]; Miller et al. 2009).

Aeolian systems are determined by the interactions of three main factors: sediment supply, sediment availability (i.e., its ability to be transported by the wind), and wind transport capacity (Kocurek and Lancaster 1999). Miller (Miller et al. 2009) describes aeolian-driven soil formation as a process that “proceeds by progressive infiltration of fine-grained dust, chemical deposition, and weathering within sediment deposits.” This process results in soil layering that strongly affects the water permeability and moisture-holding capacities of desert soils. This layering, or soil profile, is more pronounced in older soils. One by-product of aeolian processes is desert pavement, which is described in more detail in Section III.4.2.2.4.

Sand dune systems form where winds are consistently strong enough to lift just above the ground and push (or “saltate”) fine sand grains across the dune surface, especially where there is little or no vegetation to stabilize the loose soil. Sandy alluvium in dry washes and alluvial fans are sources for these materials, and strong winds generally transport the sands to areas at the mountain front where decreasing winds deposit sand (Harden 2004). Except in high-force winds, wind does not typically suspend and transport sand high into the air. The sand forming the Algodones Dunes in the southeastern portion of the Plan Area, for example, originated in the sandy delta of the Colorado River. The dunes currently extend about 43 miles from the southeast portion of the Salton Sea to the U.S.–Mexico border and can be over 300 feet high (Harden 2004).

Fluvial, Alluvial, and Lacustrine Processes

Water exerts a stronger but more intermittent force on desert surface sediments than wind. The majority of the surficial geology of the Plan Area is alluvium (shown as sedimentary in Figure III.4-1, Surficial Geology), which is from flowing water that, over geological time, carries materials from the mountains and deposits them at their base, creating broad alluvial fans of unconsolidated sediment.

Desert fluvial processes generally relate to the drainage system of distant hill slopes and channels. These processes are generally short-lived, severe events related to thunderstorms in the distant hills, which can create fast-moving debris flows and cause flash flooding on alluvial fans. Generally, the size of an alluvial fan is proportional to the size of its drainage network upslope (Harden 2004).

Lacustrine processes are most prominent in desert dry lakes or playas, which are generally low spots in drainage basins that capture fine grain sediments and surface water. These low points may also be influenced by shallow or emergent groundwater. Such areas are technically base-level plains in desert drainage basins (Cooke and Warren 1973). Playas are large flat areas dominated by fine-grained sediments (e.g., clay and evaporite minerals). These fine-grained sediments make playas relatively impermeable. Surface water is removed by infiltration and evaporation. Groundwater is removed by evaporation, evapotranspiration (or evaporation and transpiration by vegetation), and by groundwater outflow into neighboring basins if fluid pathways exist. During wet periods surface water accumulates, causing sedimentation onto playa or lakebed surfaces. Overall, the hydrologic characteristics of a playa are affected by climate, basin floor conditions, soil and vegetation, and water salinity, which affects evaporation rates.

Mass-Wasting Processes

Mass wasting refers to the downslope movement, under the direct influence of gravity, of rock, rock and mineral fragments, and soil (Nelson 2011). Mass-wasting processes include creep, slides, and debris flows. Slides are the sudden downslope movements of rock and sediment. Debris flows are dense, fluid mixtures of rock, sediment, and water.

While mass wasting in the Plan Area occurs primarily as rock falls and rockslides on steep slopes, larger events could also potentially occur. Large events are often connected to either existing faults or new seismic activity. Intense monsoonal rains and earthquakes are the primary causes of rock falls and rockslides on steep, mountain slopes in the Plan Area. Creep, on the other hand, is a slow, continuous downslope movement primarily caused by freeze/thaw or wet/dry cycles (California Department of Conservation 2007); creep therefore occurs only in small areas at high elevations.

III.4.2.2 Soils

Soil type can directly affect the site suitability for renewable energy projects. Soil types also can be indicators for the potential for valuable habitat, as explained in Chapter III.7 (Biological Resources), but this chapter focuses on the non-biological values. Table R1-4-2 (in Appendix R1) presents a complete list of the acreage for various soil textures for the Plan Area. Table III.4-1 summarizes soil types within the Plan Area.

Table III.4-1
Soil Types and Textures within the Plan Area

Soil Type	Definition	Textures	Acres
Clay	A stiff, sticky (when wet) fine-grained soil, often forming an impermeable layer in a soil profile.	Clay, silty clay, clay loam	589,000
Sand	A loose granular soil resulting from the erosion of siliceous and other rocks and usually containing only small amounts of organic matter	Fine to coarse sand; cobbly or gravelly sand; Loamy sand	8,340,000
Loam	A fertile soil of clay, silt, and sand containing organic components formed by decomposition of microorganisms and plant biomass	Fine, gravelly, sandy, or silty	8,457,000
Bedrock	Solid rock on the surface or underlying loose deposits such as soil or alluvium.	Unweathered bedrock	4,190,000
		Weathered bedrock	822,000
Unknown	n/a	Not Mapped	188,000
		Total	**22,585,000**

Source: California Department of Conservation 2010.
Note: The following general rounding rules were applied to calculated values: values greater than 1,000 were rounded to nearest 1,000; values less than 1,000 and greater than 100 were rounded to the nearest 100; values of 100 or less were rounded to the nearest 10, and therefore totals may not sum due to rounding. In cases where subtotals are provided, the subtotals and the totals are individually rounded. The totals are not a sum of the rounded subtotals; therefore the subtotals may not sum to the total within the table.

Soil types and textures for each ecoregion subarea are presented in Tables R1.4-3 through R1.4-12, in Appendix R1.

In addition to soil types, soil conditions are important characteristics of the desert environment and geologic setting of the Plan Area. They include desert pavement, erosive (e.g., carbonate, high-silt) soils, corrosive soils (saline), and expansive (high-clay) soils. Each is described in the following paragraphs. Biotic soil crusts are addressed in Section III.4.2.2.4 Biological Soil Crusts, as well as in Section III.7.3.3 Soil Biota.

III.4.2.2.1 Soils Prone to Erosion

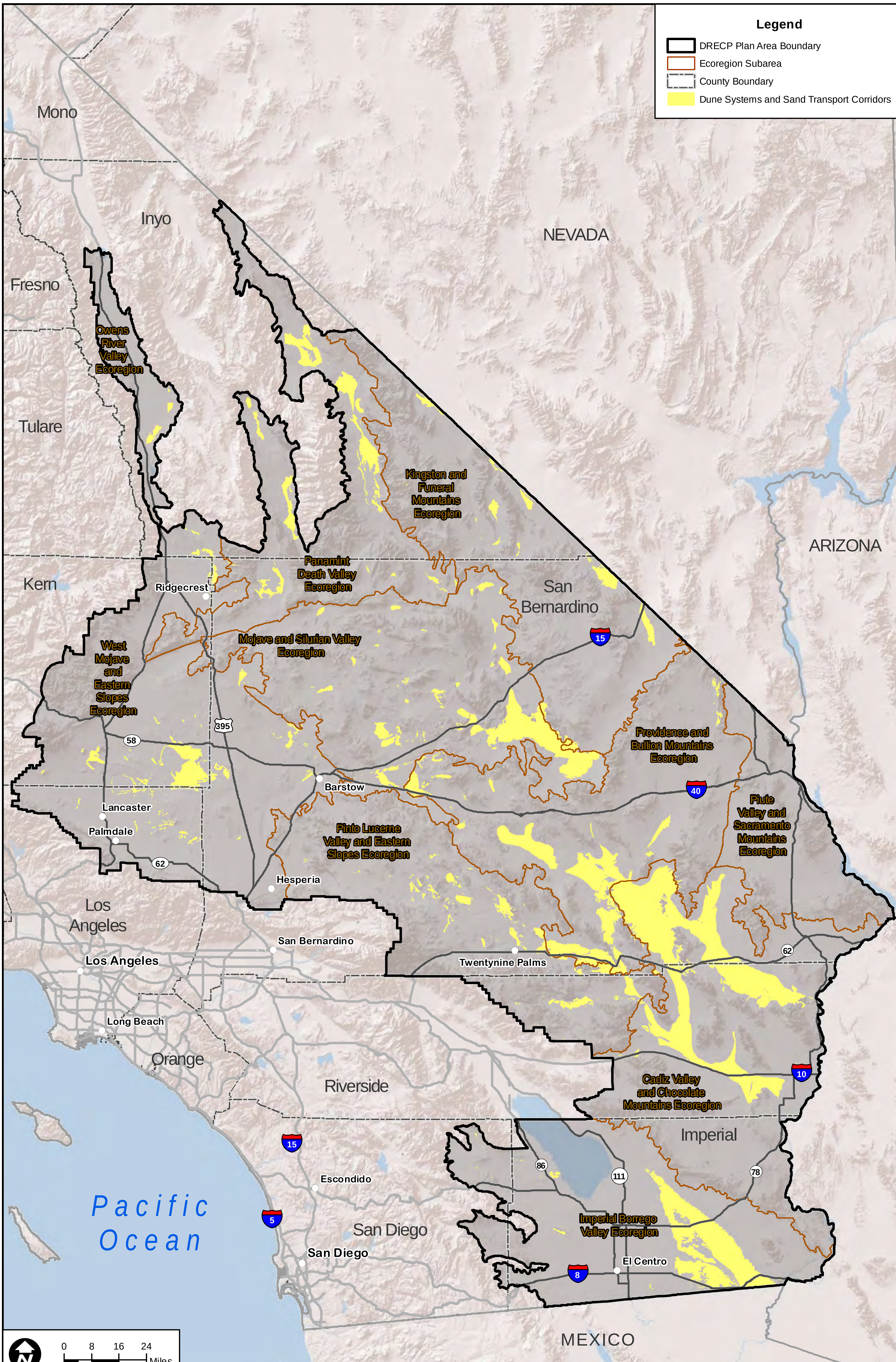
Wind and water erosion are the primary generating forces for surface features in desert climates. Surface features prone to erosion from wind and water include steep slopes, playas, bajadas, washes, alluvial fans, and sand dunes. Erosion occurs when wind or water propels fine-grained soil components. Multiple factors influence the quantity of soil loss from wind and water erosion including soil texture, soil structure, vegetation cover, permeability, land use, and topography.

Soil texture is the primary factor in determining soil's erodibility. Soil textures dominated by silt or very fine sand are the most highly erodible by wind because soil particles are not bound together by electrochemical bonds as they are in clays; they are therefore easily detached (not too heavy). Aggregated soils that are more closely bound together with high amounts of soil organic matter are less erodible since their more cohesive soil particles are larger and can better resist erosional action from wind and water. Highly permeable soils are the most resistant to erosion since a greater proportion of rainfall seeps into them, thereby diminishing runoff and promoting soil compaction. The amount of vegetation cover and land use also influences a soil's susceptibility to wind or water erosion.

III.4.2.2.1.1 Sand Transport Corridors

The Chuckwalla Valley of the Mojave Desert, located along Interstate 10 between Blythe and Desert Center, is an example of a sand transport corridor. This valley supports sand dune habitats that depend upon delivery of fine sand from aeolian and fluvial processes. These sand dunes have an active layer of mobile sand, and exist in a state of dynamic equilibrium as they continuously lose sand downwind and gain sand upwind. Dunes move within sand transport corridors. At Palen Dunes in the Chuckwalla Valley, dune migration rates were as high as 50 meters per year, totaling 1,373 meters in 27 years (1984-2011), predominantly in a southern direction (Potter and Li 2014). The overall size of active dune fields increased significantly from 1984-2011.

Active sand dunes, such as Palen Dunes, Dumont Dunes, Algodones Dunes, and Kelso Dunes, also provide important habitat for species (e.g., the Mojave fringe-toed lizard) that rely on a regular supply of wind-blown sand. Based on land-cover mapping of North American warm desert dunes and sand flats, there are about 1,781,000 acres of sand transport corridors and dune systems within the Plan Area (Data Basin 2014[a]). See Figure III.4-2 Dune Systems and Sand Transport Corridors within the Plan Area, for the distribution of sand transport corridors.



Sources: ESRI (2014); CEC (2013); DATABASIN (2014b)

FIGURE III.4-2

Dune Systems and Sand Transport Corridors within the Plan Area

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III.4.2.2.2 Corrosive Soils (Saline, Gypsic, and Sodic Soil)

Depending on its chemical composition, soil may be corrosive to buried steel, concrete, other construction materials, and on-site equipment. Soil corrosion can potentially create geologic hazards that could undermine the long-term integrity of renewable energy project infrastructure. Soil resistivity is the ability of soil to allow electrons to move through it. A low resistivity means that a soil is a good electron conductor and thus a stronger corrosive agent. A soil with resistivity between 2,000 to 5,000 Ohm-centimeters is considered "moderately corrosive" to ungalvanized steel, while soils with a resistivity between 5,000 to 10,000 Ohm-centimeters are considered "mildly corrosive." The predominant soil type in the Plan Area is alluvium, which has a resistivity ranging from 1,428 to 10,000 Ohm-centimeters (USDOT 2009).

Corrosive desert soils have high contents of chloride, sodium, or sulfate minerals. Soils with high amounts of sulfate minerals, such as gypsum, are harmful to concrete, particularly when soil moisture is acidic (low pH). High chloride concentrations from saline minerals can corrode metals. Many of the soils that develop on or near playas contain unusually high quantities of saline and sodic minerals, which are left behind from stormwater evaporation. Certain playas (e.g., Searles Lake) produce commercially valuable corrosive minerals such as trona, which is corrosive to steel.

Vegetation in the desert is specifically adapted to its soil characteristics. Playas are fairly devoid of vegetation due to their highly alkaline soils. Wetland habitats known as "North American warm desert alkaline scrub and herb playa and wet flat" are widespread in the Plan Area. The presence of playas indicates potentially corrosive soil. Using these two vegetation types to help identify likely corrosive soils, there is an estimated 509,000 acres of potentially corrosive soil within the Plan Area (Data Basin 2014b). See Figure III.4-3, Potentially Corrosive Soils within the Plan Area.

III.4.2.2.3 Expansive Soils

Expansive soil volumes can change significantly with variations in soil moisture content. Expansive soils are typically fine grained, with a high percentage of clay that expands and contracts as soil moisture content fluctuates. Clay soil expansion and contraction can damage building foundations, concrete flatwork, and asphalt or concrete pavements through uplift and swelling. As shown in Table III.4-1, there are nearly 589,000 acres of predominantly clay soil within the Plan Area. See Figure R1.4-1 through Figure R1.4-10 in Appendix R1 for soil textures, by ecoregion subarea. See also Tables R1.4-3 through R1.4-12, in Appendix R1.

III.4.2.2.4 Desert Pavement

Desert pavement is composed of close-packed angular or rounded rock fragments with an often dark varnish cover. These layers cover fine-grained silt and clay particles beneath the rock pavement surface. The interstitial and underlying material can be highly calcareous with low permeability. Desert pavements form in the most arid parts of the Plan Area where average annual rainfall is less than 8 inches. These areas typically support a sparse seasonal cover of ephemeral plants and few, if any, perennial plant species. Desert pavement generally overlies older alluvium formations within the Plan Area. Topographically, pavements tend to form along the middle elevations of alluvial fans, where stormflow runs along distinct down-cut channels between raised areas of desert pavement. The tightly packed and caliche-rich (calcium carbonate) surface of desert pavement inhibits infiltration of precipitation and promotes runoff, which funnels water into adjacent small channels. Aeolian processes facilitate the formation of desert pavements. If desert pavement is damaged by vehicle traffic or grading, it loses its armoring function and can increase the likelihood of soil erosion from surface runoff.

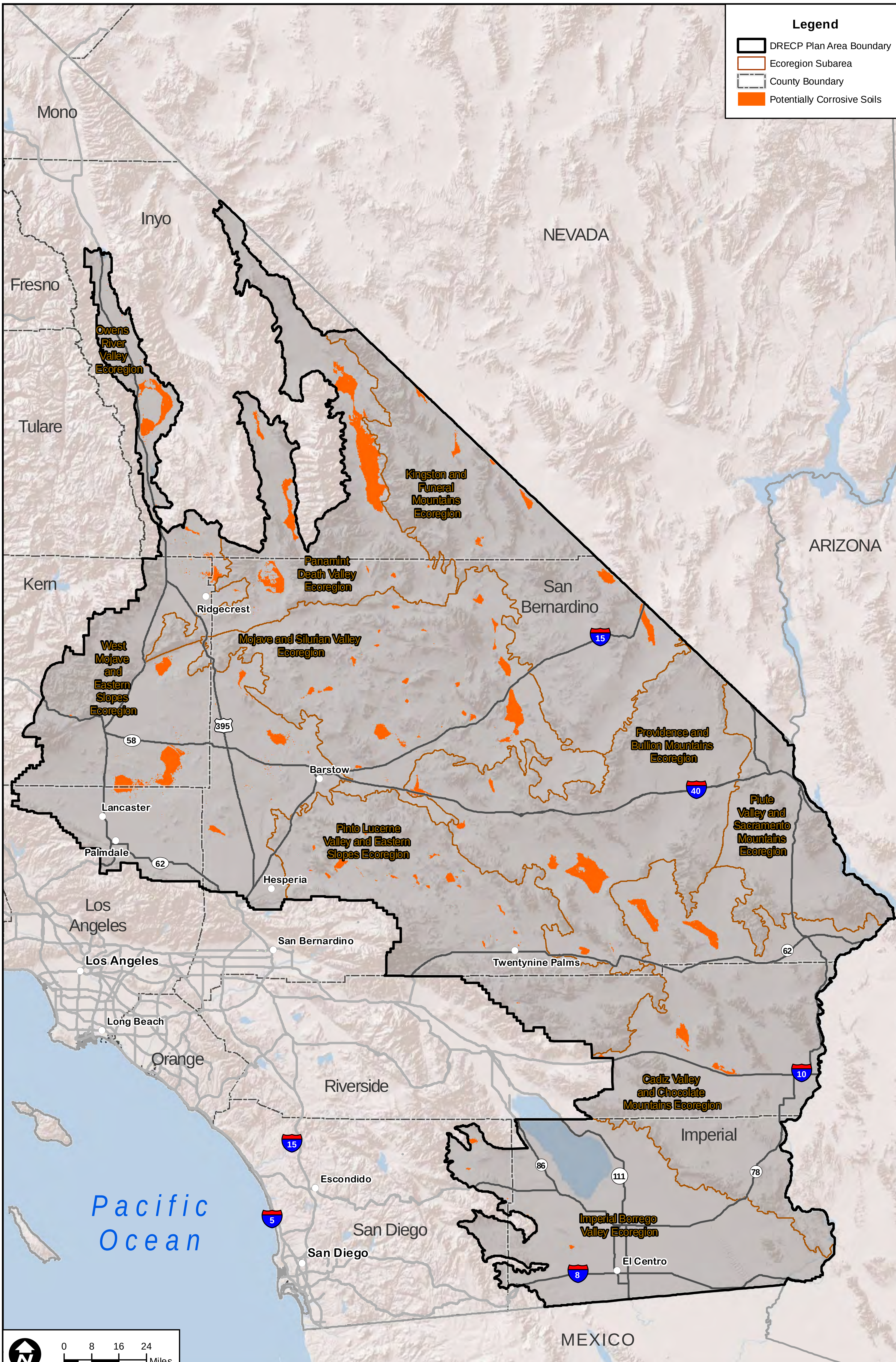
III.4.3 Faulting and Seismicity

Earthquakes happen when large masses of subsurface rock move against each other along fractures called faults. The shaking from earthquakes can be significant, and can be felt many miles from their actual epicenters, depending on the type of earthquake and the characteristics of underlying soils and geology (BLM 2008).

Earthquakes can cause property damage and loss of life. Seismic hazards include ground shaking, landslides and rockfalls, liquefaction, and ground ruptures (surface faulting). Most widespread damage and loss of life results from ground shaking, because it can cause structure failures and collapses, even at great distances from the fault rupture (U.S. Geological Survey [USGS] 2012). Specific potential seismic hazards in the Plan Area are described in Section III.4.4.

There are approximately 1,000 known earthquake faults within the Plan Area, as shown in Figure III.4-4, Earthquake Faults within the Plan Area. The largest are the San Andreas and San Jacinto faults, which are in the Imperial Borrego Valley ecoregion subarea. The San Andreas Fault also extends through the West Mojave and Eastern Slopes ecoregion subarea.

The assessment of risk from earthquakes is complex and usually expressed as zones of probability for given accelerations from shaking. The highest hazard risk within the Plan Area occurs along the San Andreas and San Jacinto faults, along the western boundary of the Plan Area, and within Imperial Valley. Figure III.4-5 through Figure III.4-12 shows existing earthquake faults by ecoregion subarea. Not all ecoregion subareas have earthquake faults. Figure III.4-13, Peak Horizontal Ground Acceleration within the Plan Area, shows the peak accelerations with a 10% chance of being exceeded within the next 50 years.



Sources: ESRI (2014); CEC (2013); DATABASIN (2014b)

FIGURE III.4-3

Potentially Corrosive Soils within the Plan Area

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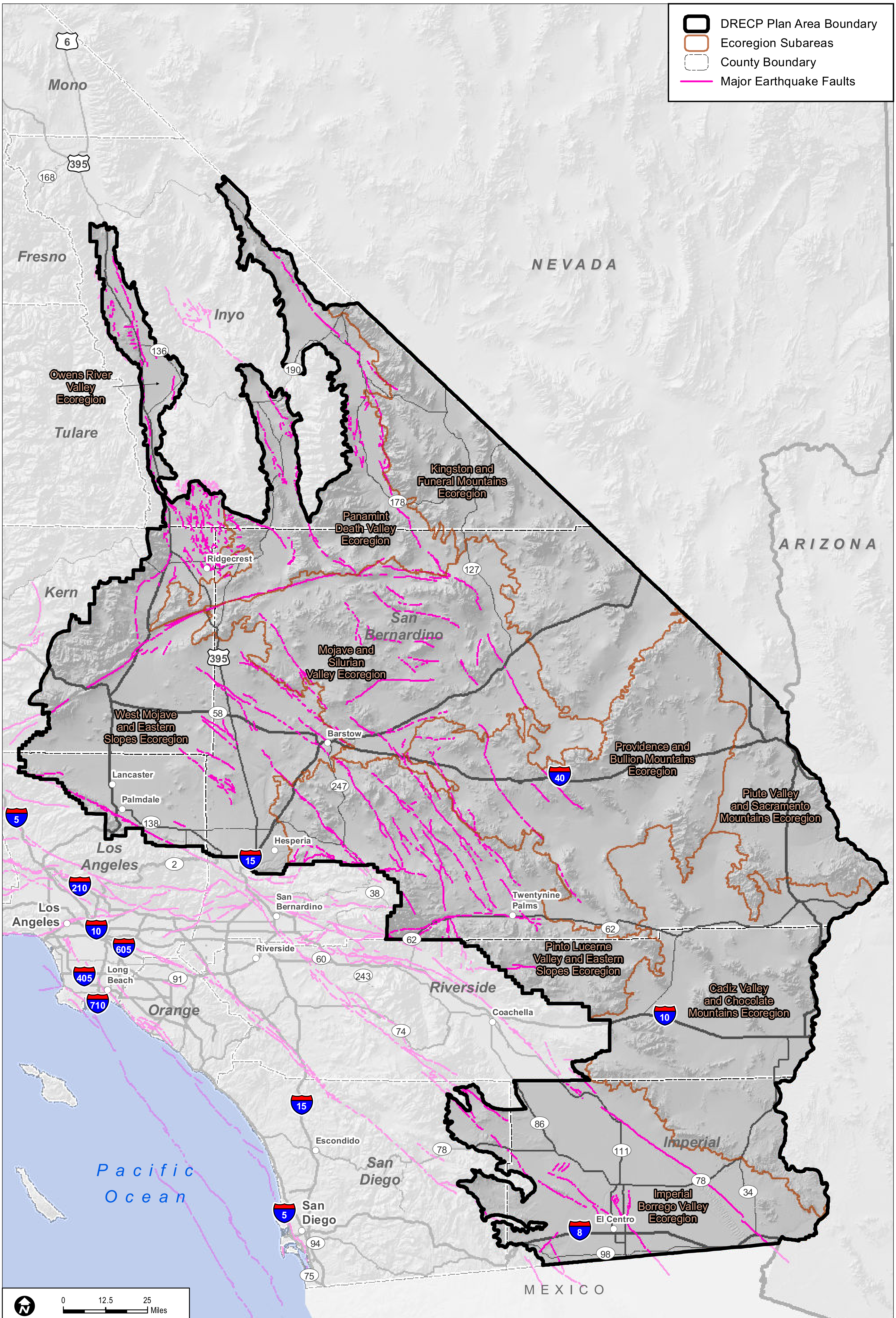

Sources: ESRI (2014); CEC (2013); BLM (2013); CDFW (2013); USFWS (2013); CA Dept. of Conservation, Division of Mines and Geology (1994)

FIGURE III.4-4

Earthquake Faults within the Plan Area

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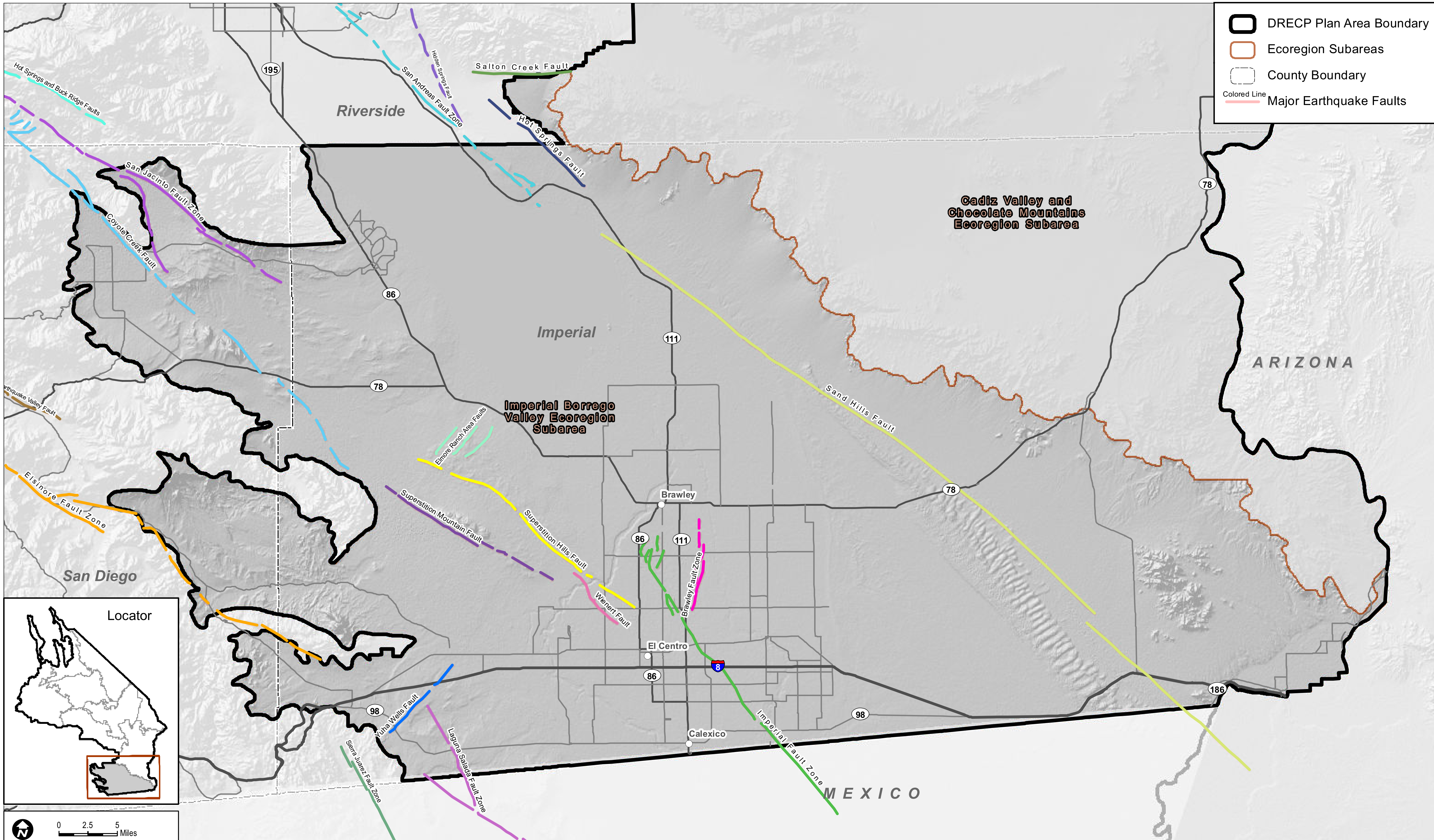

Sources: ESRI (2014); CEC (2013); BLM (2013); CDFW (2013); USFWS (2013); CA Dept. of Conservation, Division of Mines and Geology (1994)

FIGURE III.4-5

Earthquake Faults within the Imperial Borrego Valley Ecoregion Subarea

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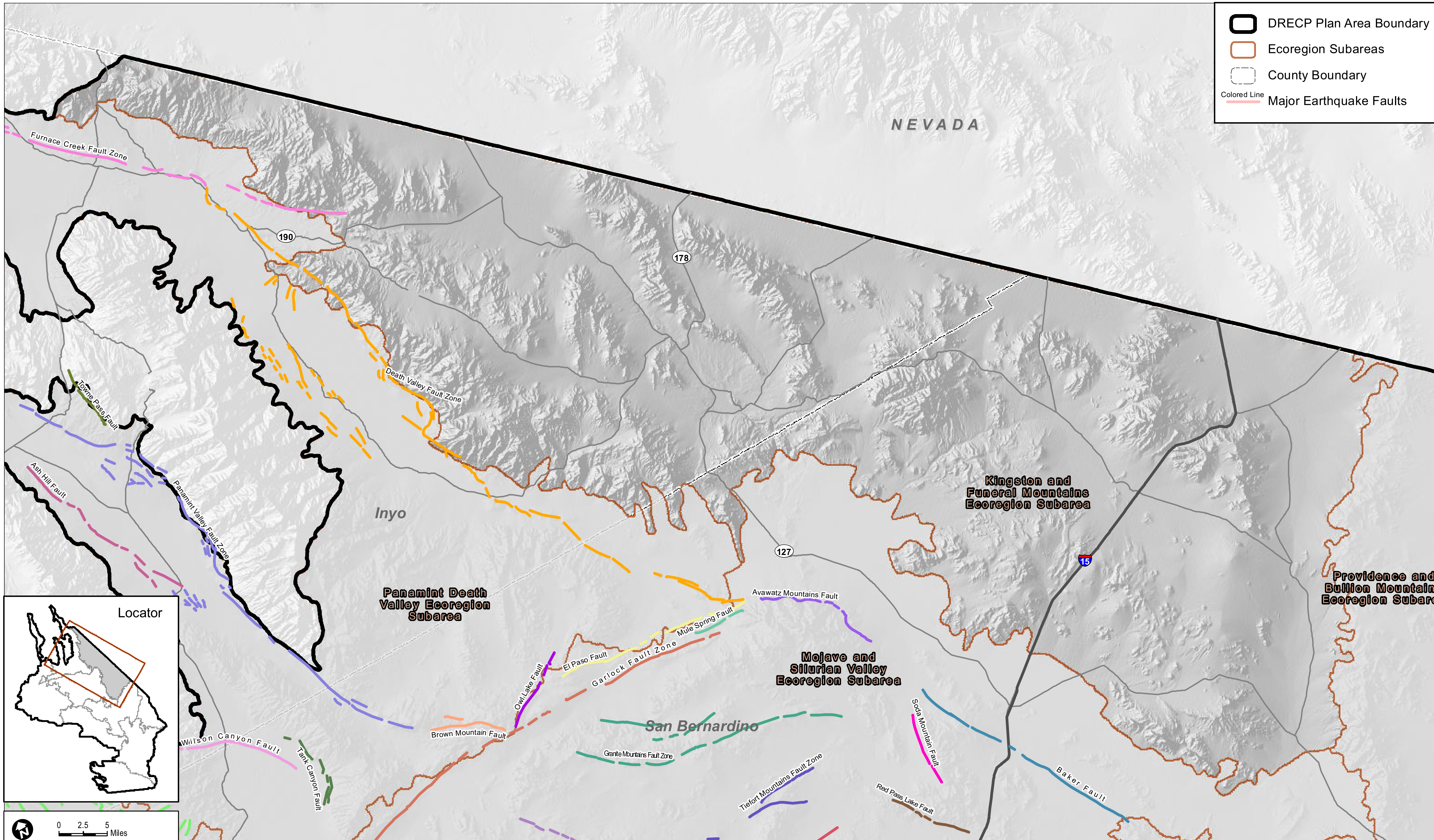

Sources: ESRI (2014); CEC (2013); BLM (2013); CDFW (2013); USFWS (2013); CA Dept. of Conservation, Division of Mines and Geology (1994)

FIGURE III.4-6

Earthquake Faults within the Kingston and Funeral Mountains Ecoregion Subarea

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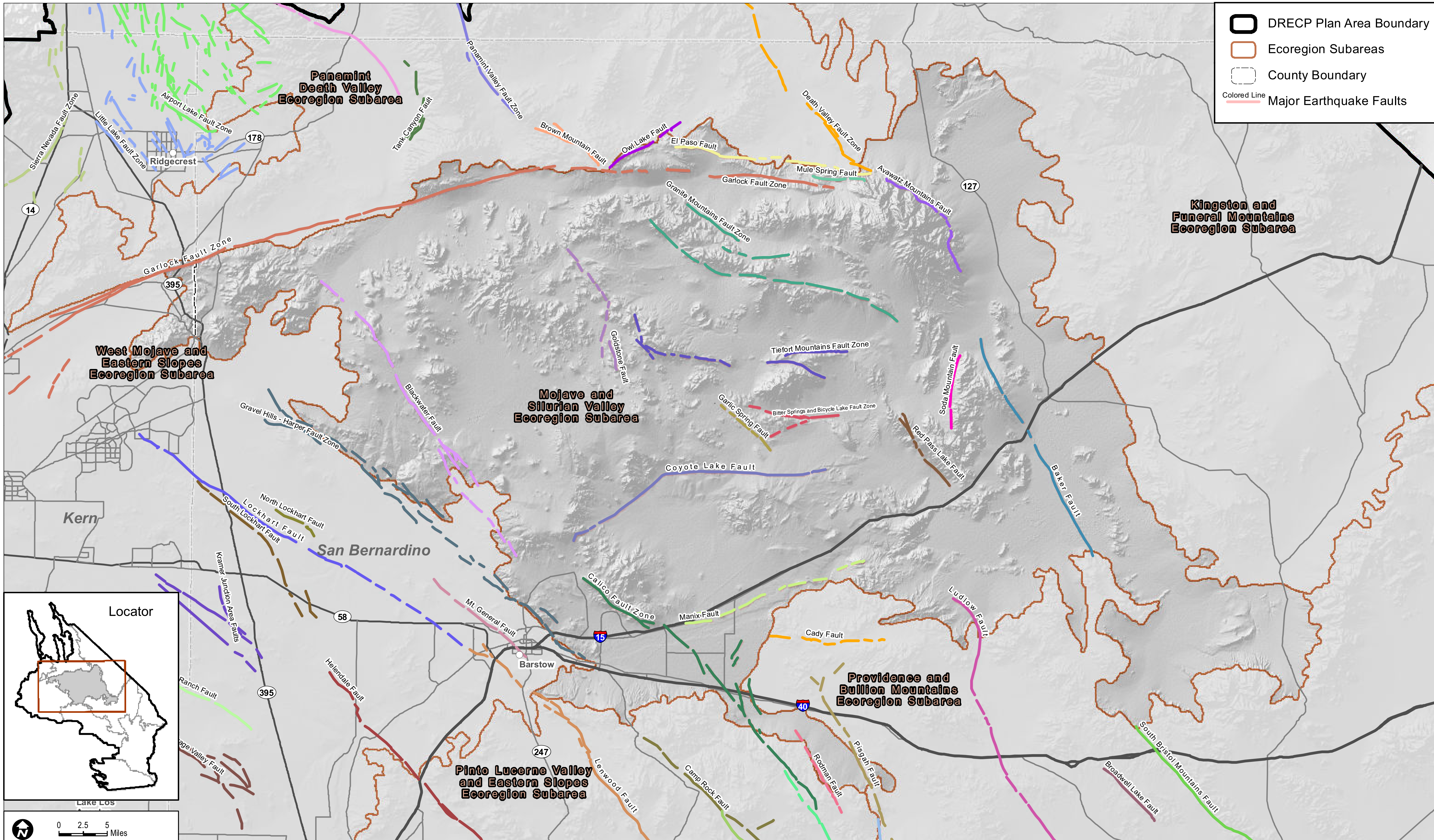

Sources: ESRI (2014); CEC (2013); BLM (2013); CDFW (2013); USFWS (2013); CA Dept. of Conservation, Division of Mines and Geology (1994)

FIGURE III.4-7

Earthquake Faults within the Mojave and Silurian Valley Ecoregion Subarea

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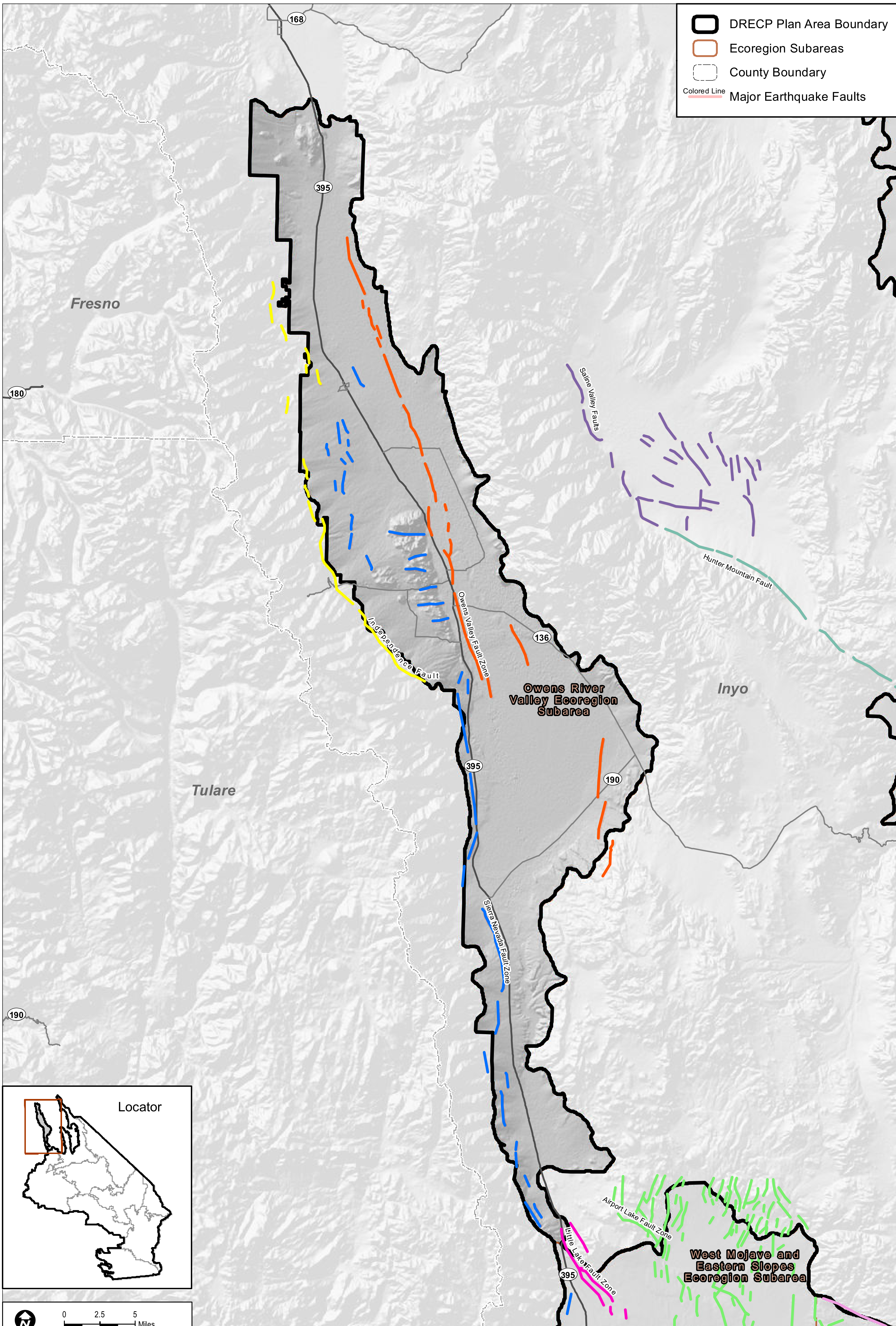

Sources: ESRI (2014); CEC (2013); BLM (2013); CDFW (2013); USFWS (2013); CA Dept. of Conservation, Division of Mines and Geology (1994)

FIGURE III.4-8

Earthquake Faults within the Owens River Valley Ecoregion Subarea

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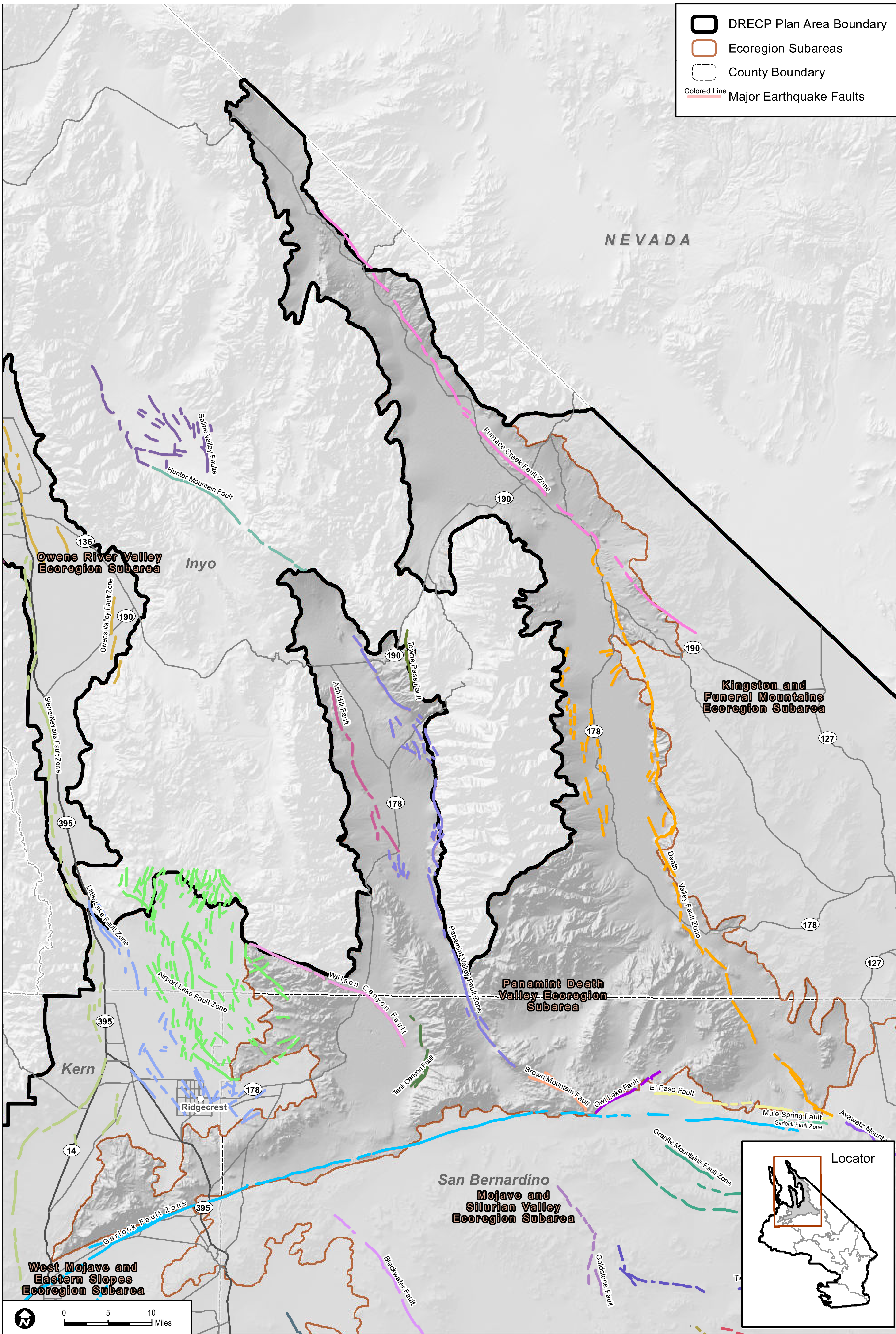

Sources: ESRI (2014); CEC (2013); BLM (2013); CDFW (2013); USFWS (2013); CA Dept. of Conservation, Division of Mines and Geology (1994)

FIGURE III.4-9

Earthquake Faults within the Panamint Death Valley Ecoregion Subarea

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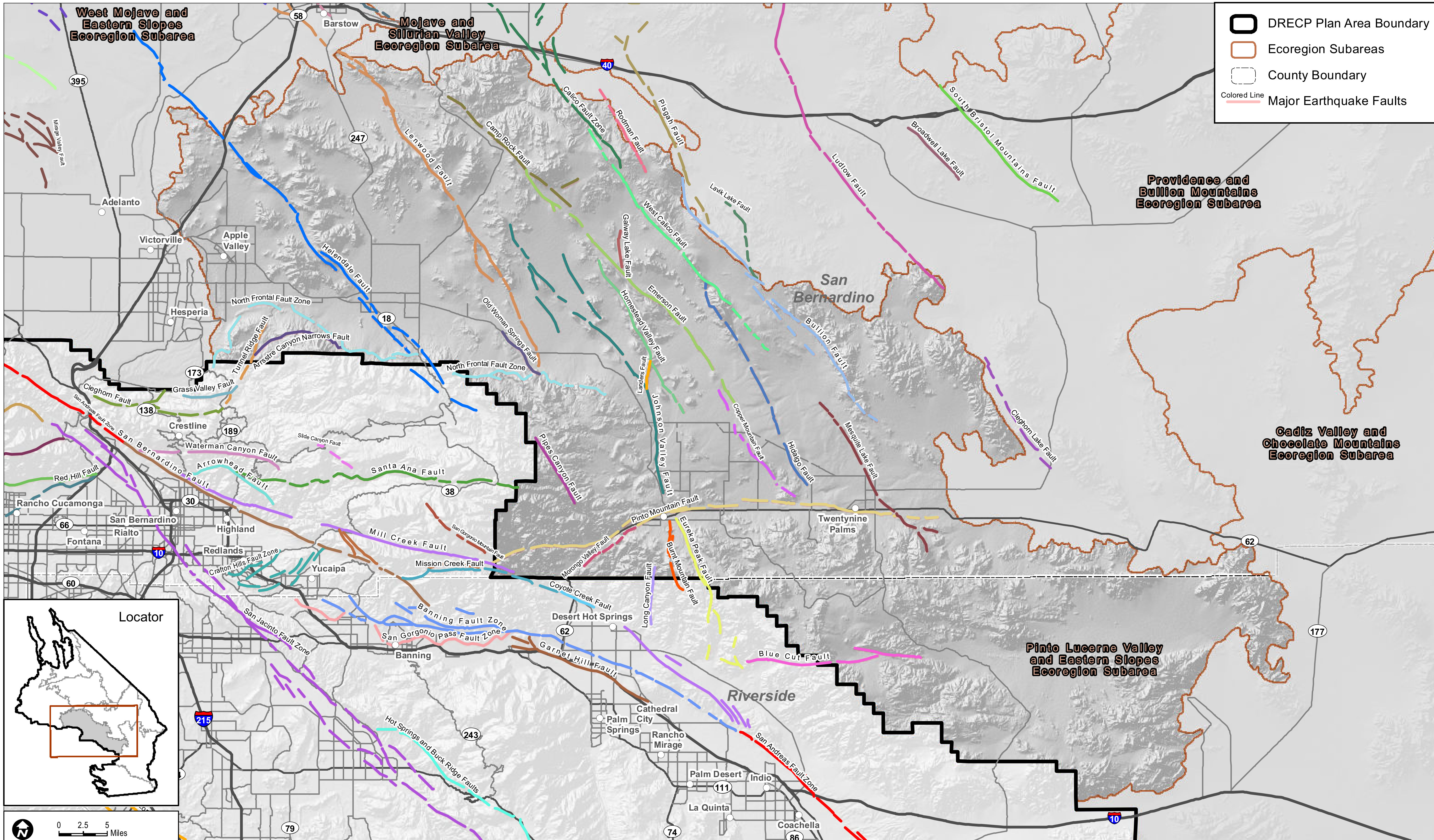

Sources: ESRI (2014); CEC (2013); BLM (2013); CDFW (2013); USFWS (2013); CA Dept. of Conservation, Division of Mines and Geology (1994)

FIGURE III.4-10

Earthquake Faults within the Pinto Lucerne Valley and Eastern Slopes Ecoregion Subarea

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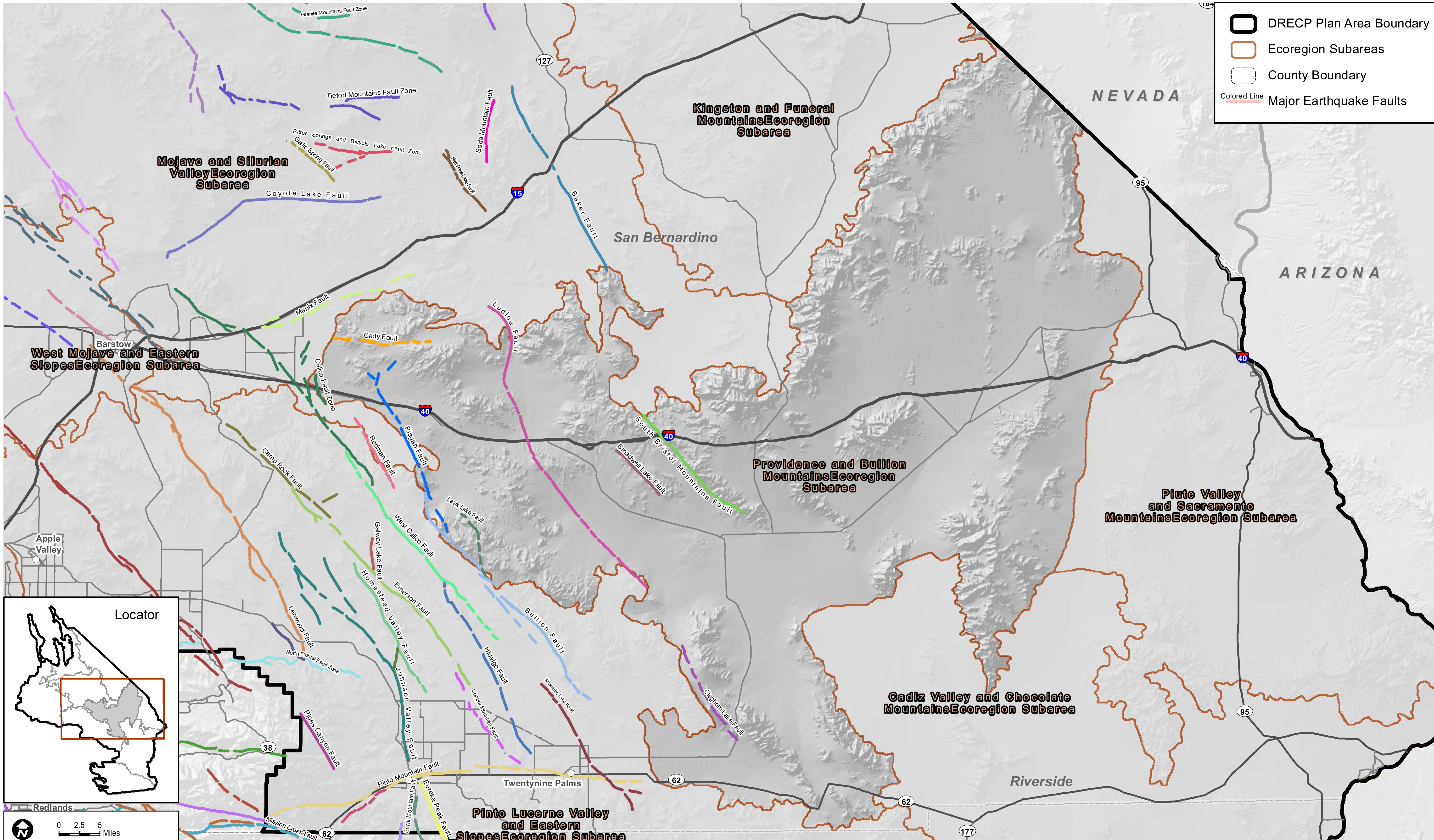

Sources: ESRI (2014); CEC (2013); BLM (2013); CDFW (2013); USFWS (2013); CA Dept. of Conservation, Division of Mines and Geology (1994)

FIGURE III.4-11

Earthquake Faults within the Providence and Bullion Mountains Ecoregion Subarea

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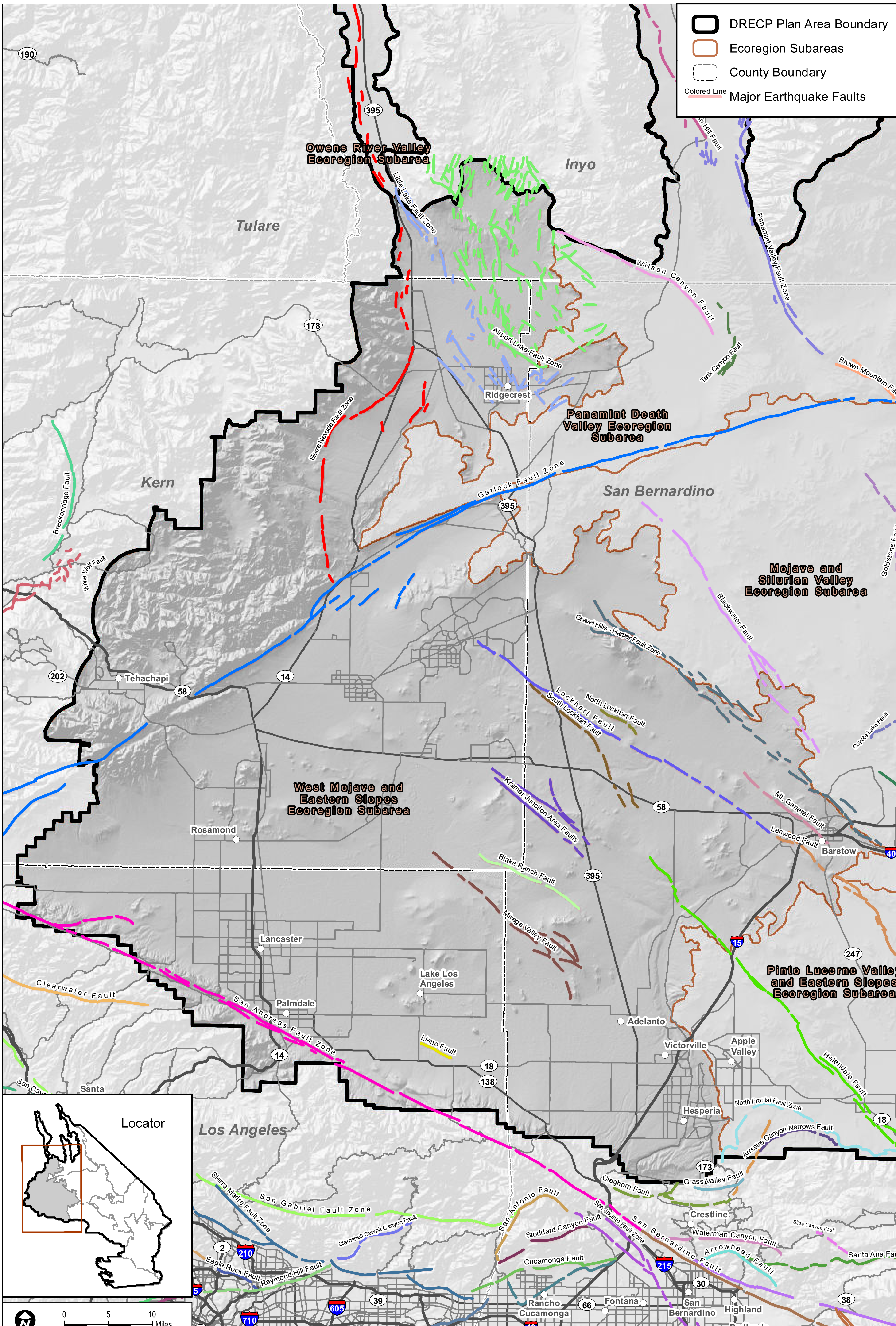

Sources: ESRI (2014); CEC (2013); BLM (2013); CDFW (2013); USFWS (2013); CA Dept. of Conservation, Division of Mines and Geology (1994)

FIGURE III.4-12

Earthquake Faults within the West Mojave and Eastern Slopes Ecoregion Subarea

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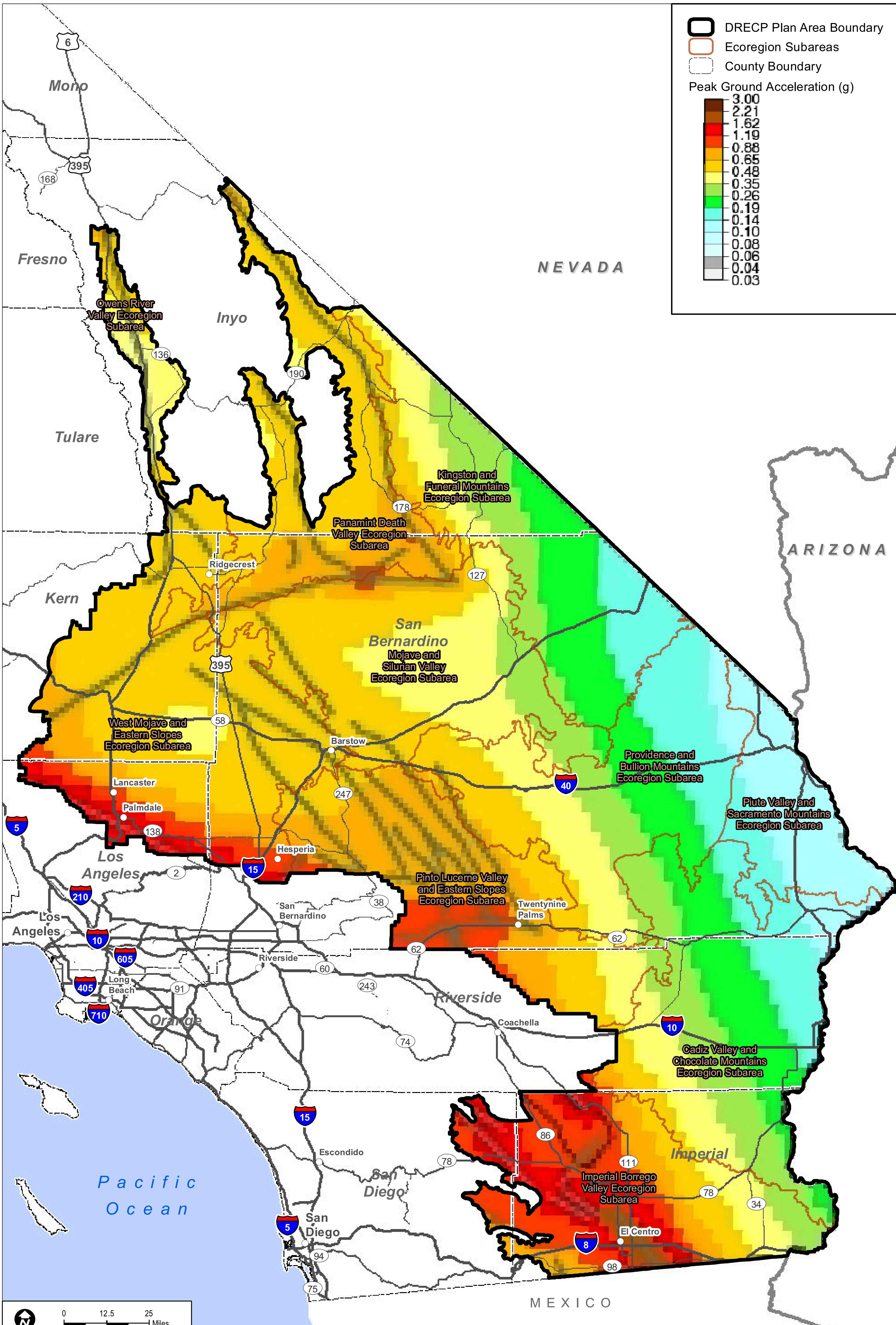

Sources: ESRI (2014); CEC (2013); BLM (2013); CDFW (2013); USFWS (2013); U.S. Geological Survey National Seismic Hazard Maps (2008)

FIGURE III.4-13

Peak Horizontal Ground Acceleration within the Plan Area (Lands with a 10% probability of exceedance within 50 years)

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Earthquake magnitude is measured on the Richter magnitude scale, a logarithmic scale that measures the amplitudes of the waves of motion 100 km from the epicenter of an earthquake. Table III.4-2, Largest Faults within the Plan Area, lists the largest faults based on the probable Richter-magnitude they could generate. The table presents the fault name, magnitude of earthquake capable of being generated, the ecoregion subarea in which it is located and the length of each fault. Also in the table is whether the fault is within an Alquist-Priolo Fault Zone. According to the Alquist-Priolo Earthquake Fault Zoning Act (1972), fault zones are distinguished from faults based on the potential for surface fault rupture and whether the fault is active. The USGS Earthquake Glossary defines active faults as those that have moved within the last 11,000 years (USGS 2014).

Table III.4-2
Largest Faults within the Plan Area

Fault (Alquist-Priolo Fault Zones indicated with asterisks)	Probable Richter magnitude	Ecoregion Subarea(s)	Length of Fault per Ecoregion (miles)
San Andreas Fault*	6.8 – 8.0	Imperial Borrego Valley	7.3
		West Mojave and Eastern Slopes	60.8
Furnace Creek Fault	6.8 – 7.6	Kingston and Funeral Mountains	4.7
		Panamint Death Valley	40.2
Garlock Fault*	6.8 – 7.6	Mojave and Silurian Valley	30.8
		Panamint Death Valley	20.7
		West Mojave and Eastern Slopes	70.0
Owens Valley Fault*	6.5 – 8.2	Owens River Valley	41.4
Coyote Creek Fault	6.5 – 7.5	Imperial Borrego Valley	24.8
Elsinore Fault*	6.5 – 7.5	Imperial Borrego Valley	4.5
Laguna Salada Fault	6.5 – 7.5	Imperial Borrego Valley	7.0
Pinto Mountain Fault*	6.5 – 7.5	Pinto Lucerne Valley and Eastern Slopes	43.3
San Jacinto Fault*	6.5 – 7.5	Imperial Borrego Valley	25.3
Panamint Valley*	6.5 – 7.5	Panamint Death Valley	58.1
Lenwood Fault*	6.5 – 7.4	West Mojave and Eastern Slopes	6.1
Lockhart Fault	6.5 – 7.4	West Mojave and Eastern Slopes	33.3
North Lockhart Fault	6.5 – 7.4	West Mojave and Eastern Slopes	4.6
Death Valley Fault*	6.5 – 7.3	Kingston and Funeral Mountains	13.8
		Mojave and Silurian Valley	1.4
		Panamint Death Valley	89
Emerson Fault	6.5 – 7.3	Pinto Lucerne Valley and Eastern Slopes	30.3
Helendale Fault*	6.5 – 7.3	Pinto Lucerne Valley and Eastern Slopes	37.2
Johnson Valley Fault*	6.5 – 7.3	Pinto Lucerne Valley and Eastern Slopes	42.2

Table III.4-2
Largest Faults within the Plan Area

Fault (Alquist-Priolo Fault Zones indicated with asterisks)	Probable Richter magnitude	Ecoregion Subarea(s)	Length of Fault per Ecoregion (miles)
Gravel Hills – Harper Fault	6.5 – 7.2	West Mojave and Eastern Slopes	35.3
Blackwater Fault	6.5 – 7.1	West Mojave and Eastern Slopes	4.6
Bullion Fault*	6.5 – 7.1	Pinto Lucerne Valley and Eastern Slopes	26.1
		Providence and Bullion Mountain	9.4
Calico Fault*	6.5 – 7.1	Pinto Lucerne Valley and Eastern Slopes	9.8
		Providence and Bullion Mountain	2.8
North Frontal Fault Zone*	6.0– 7.1	Pinto Lucerne Valley and Eastern Slopes	39.2
Manix Fault*	6.0 – 7.0	Mojave and Silurian Valley	14.4
Mesquite Lake Fault*	6.0 – 7.0	Pinto Lucerne Valley and Eastern Slopes	17.3
Superstition Hills Fault*	6.0 – 6.8	Imperial Borrego Valley	19.7
Little Lake Fault Zone*	5.5 – 7.0	Owens River Valley)	0.8
		Panamint Death Valley	3.3
		West Mojave and Eastern Slopes	52.9
Brawley Fault Zone*	5.0 – 6.5	Imperial Borrego Valley (9.2)	9.2

Sources: Southern California Earthquake Data Center 2012; California Geologic Survey 2007

III.4.4 Other Geologic Hazards

This section addresses several different types of hazards. Of the geologic hazards that could affect renewable energy projects, two could result from fault movement: ground shaking and liquefaction. Other hazards that could occur in the Plan Area include subsidence and volcanic activity.

III.4.4.1 Ground Shaking

Earthquakes are the principal geologic activities affecting public safety and structures throughout most of California. The ground shaking from earthquakes creates various secondary hazards including:

- Differential ground settlement.
- Soil liquefaction, rock and mudslides, ground lurching, and avalanches.
- Ground displacement along the fault.
- Floods from dam or levee failures.

- Fires.
- Disruptions to water, sewer, gas, electricity, transportation, and communication services.

The intensity of ground shaking during an earthquake is dependent upon (1) the distance between a project area and the epicenter (point at the earth's surface directly above the initial movement of the fault at depth) of the earthquake, (2) the magnitude or size of the earthquake, (3) the depth at which the earthquake occurs, and (4) the underlying geologic conditions. A commonly used benchmark for intensity is peak horizontal ground acceleration, which is the probability that an earthquake will exceed the peak acceleration of gravity value (g) by 10%. Peak horizontal ground acceleration is the ground motion effect at a site for all earthquakes believed to be possible at that site. Figure III.4-13, Peak Horizontal Ground Acceleration within the Plan Area, shows these zones mapped for the DRECP area. Table III.4-3, Earthquakes within the Plan Area with a Magnitude 6.0 or Higher, lists large earthquakes that have occurred within the Plan Area over the last 75 years.

Table III.4-3
Earthquakes within the Plan Area with a Magnitude 6.0 or Higher

Earthquake Name	Date	Magnitude	Location
Hector Mine Earthquake	October 16,1999	7.1	North of Twentynine Palms
Landers Earthquake	June 28,1992	7.3	Yucca Valley
Superstition Hills Earthquake	November 24, 1987	6.6	West of Brawley
Borrego Mountain Earthquake	April 9, 1968	7.0	East of Borrego Springs
Imperial Valley Earthquake	May 18, 1940	6.9	North of Calexico
Walker Pass Earthquake	March 15, 1946	6.0	West of Ridgecrest
Manix Earthquake	April 10, 1947	6.5	East of Newberry Springs
Imperial Valley Earthquake	October 15, 1979	6.4	West of El Centro
1954 San Jacinto Fault	March 19, 1954	6.4	East of Borrego Springs
San Jacinto Fault	March 25, 1937	6.0	Northeast of Borrego Springs

Source: SCEC (2014)

III.4.4.2 Liquefaction

Liquefaction can occur in loose, fine-to-medium-grained soils that are water-saturated, in areas where the groundwater table is within approximately 50 feet of the ground surface. Earthquake shaking causes the soil to weaken, resulting in its inability to stick together; the soil therefore behaves as a liquid. Liquefaction can result in loss of the soils' ability to support a load such as a building foundation, lateral spreading, subsidence, and buoyancy effects. Susceptibility to liquefaction is a function of the sediment density, water content, soil thickness, and the peak ground acceleration of an earthquake at the location. In the 1989 Loma Prieta earthquake in the San Francisco Bay Area, liquefaction in the city's Marina District caused many large buildings to slide off their foundations, and also caused underground natural gas line ruptures that in turn caused major fires.

III.4.4.3 Subsidence

Land subsidence normally results from fluid withdrawal from groundwater pumping, oil extraction, or geothermal generation. (Logfren 1973). Fluid removal can create subsurface voids from ground surface sinking and soil permeability loss. Subsidence from shifting earth plates can also occur over large areas. Subsidence from fluid extraction can occur near geothermal areas (Logfren 1973). In the western portion of the Plan Area, groundwater levels in some basins have declined more than 100 feet from predevelopment conditions. Land subsidence could occur within the Plan Area. See Chapter III.6, Section III.6.3.4, Subsidence from Groundwater Pumping for further discussion of subsidence.

III.4.4.4 Volcanic Activity

As shown in Table R1.4-1 (Surficial Geology in the Plan Area, Appendix R1), the Plan Area includes 60,252 acres of young (Holocene) volcanic materials on the land surface. See Figure III.4-1, Surficial Geology, for the locations of this volcanic rock type.

There are several areas of potential volcanic hazards within the Plan Area. According to the U.S. Geological Survey (USGS), areas designated as "Moderate Threat Volcanoes" (defined as posing a risk to aviation and a low to very-low threat to people and property), include Ubehebe Craters in Death Valley National Park and Coso Volcanic Field in Inyo County (USGS 2005). The Plan Area includes two features deemed "High Threat Volcanos" (defined as posing significant risks to aviation and proximate to smaller population centers and power and transportation infrastructure). These high-risk features are the Salton Buttes in Imperial County and the Lavic Lake Volcanic Field in San Bernardino County.

III.4.5 Geology and Soils in Bureau of Land Management Land Use Plan Amendment

The BLM LUPA area is a subset of the total Plan Area. Geologic hazards and soils of concern are widespread within the Plan Area, so the LUPA affected environment is considered to have a similar set of resources and hazards as those defined in Sections III.4.2, III.4.3, and III.4.4 for the entire Plan Area.

III.4.6 Geology and Soils in Natural Community Conservation Plan Area

The affected environment for the NCCP area is the same as that described above for the entire Plan Area. While there are Department of Defense (DOD) lands and tribal lands within the Plan boundaries, the Plan does not analyze effects on these lands so they are not included in the description of the affected environment.

III.4.7 Geology and Soils in General Conservation Plan Area

The affected environment for the General Conservation Plan (GCP) area includes a subset of the lands covered by Plan-wide analysis and the NCCP. In addition to excluding DOD and tribal lands, the GCP lands exclude all other federal lands (e.g., BLM-administered public lands, national parks, U.S. Forest Service lands). Geologic hazards and soils of concern are widespread within the Plan Area, so the GCP affected environment has a similar set of resources and hazards as those defined in Sections III.4.2, III.4.3, and III.4.4 for the entire Plan Area.

III.4.8 Geology and Soils Outside the Plan Area

III.4.8.1 Transmission Out-of-Plan Area

This section discusses baseline geologic, seismic, and soils information for the respective study areas and surrounding regions. Resources in these regions are generally discussed using information gathered from the environmental clearance documents for four large transmission line projects.

III.4.8.1.1 San Diego Area

The San Diego area corridor extends from Ocotillo, in southwestern Imperial County, to San Diego, roughly following the existing Sunrise Powerlink Project corridor westward.

III.4.8.1.1.1 Regional Physiography

The San Diego area crosses two major physiographic provinces in California: the Colorado Desert and the Peninsular Ranges. The region is geologically complex, with a variety of rock types, faults, and geologic features. The San Diego area skirts the edges of and crosses fault-bounded mountain ranges and desert features such as playas, badlands, alluvial fans and pediments, and desert valleys bisected by numerous arroyos and washes.

The Colorado Desert region lies mostly at low elevation and consists of desert basins with interspersed northwest-trending mountain ranges. In the Colorado Desert region, the corridor is located in the Imperial Valley portion of the Salton Trough. The Salton Trough is a topographic and structural trough that extends from southeastern California into Mexico, and is about 130 miles long and as much as 70 miles wide.

The Peninsular Ranges region is divided into two geomorphic zones: the mountains of the Peninsular Ranges to the east, and the Coastal Plain to the west. The mountains of the Peninsular Ranges are predominantly north–south trending ranges that stretch 900 miles from Southern California to the southern tip of Mexico's Baja California peninsula. The Coastal Plain area consists of a "layer cake" sequence of Tertiary to late Cretaceous marine and nonmarine sedimentary rock that forms mesas and terraces primarily overlying Mesozoic granitic rocks. The terraces and mesas along the Coastal Plain were formed by fluctuations in relative elevations of the land and sea (uplift and sea level changes) (CPUC and BLM 2008).

III.4.8.1.1.2 Geology

The San Diego area is underlain in various areas by sedimentary, volcanic, igneous, and metamorphic rocks ranging in age from Quaternary (approximately the last 1.6 million years) to Pre-Cenozoic (greater than 65 million years). It encompasses lacustrine deposits, alluvial plains and valleys, alluvial fans and pediments, mountain passes, and hills (CPUC and BLM 2008).

III.4.8.1.1.3 Slopes

Most of the San Diego area does not include areas identified as existing landslides. However, some of the sedimentary rock may be susceptible to slope failures in areas with moderate to steep slopes and unfavorable bedding dip directions. There may be unmapped landslides and areas of localized slope instability in the hills. Areas underlain by granitic rocks would most likely only be susceptible to surficial soil creep or rockfall in overly steep areas (CPUC and BLM 2008).

III.4.8.1.1.4 Soils

The soils along the San Diego Area reflect the underlying rock type, the extent of weathering of the rock, the degree of slope, and the degree of human modification. The corridor crosses undeveloped land, small portions of agricultural and rural residential land, small portions of light industrial and commercial areas, and suburban residential areas.

III.4.8.1.1.5 Faults and Seismicity

The seismicity of the San Diego area is dominated by the northwest trending San Andreas Fault system. The San Andreas Fault system reacts to stress generated by the motions of the Pacific and North American Tectonic plates. The Rose Canyon-Newport Inglewood fault system and the Agua Blanca fault zone are also seismic sources that have potential to affect San Diego. However, the most significant faults in the San Diego area are those associated with the San Andreas fault system, which includes faults in the San Andreas, San Jacinto, and Elsinore fault zones:

- **San Andreas Fault Zone** is a 680-mile active right-lateral strike-slip complex of faults that has historically caused many of the damaging earthquakes in Southern California. The Coachella segment of the San Andreas Fault extends from Cajon Pass (near Bakersfield) to the Salton Sea.
- **San Jacinto Fault Zone** is a major element of the San Andreas Fault system in Southern California, with historic earthquakes (if not ground rupture) associated with most of its sections. The seismically active San Jacinto Fault zone is a complex system of strike-slip fault segments connected by releasing and restraining bends and stepovers that extend for 240 km from the San Andreas Fault near Cajon Pass through the Peninsular Ranges into the southwestern Imperial Valley.
- **Elsinore Fault Zone** is one of the largest in Southern California, extending over 155 miles from the Los Angeles Basin southeastward to the Mexico border where it continues southeast as the Laguna Salada Fault. In the project vicinity, the Elsinore Fault is double stranded, with the two strands approximately parallel to each other and separated by approximately 4 to 7.5 miles (Aspen 2008).

III.4.8.1.1.6 Liquefaction

Due to the generally deep water table (with the exception of areas immediately adjacent to the Colorado River), liquefaction is not considered a potential hazard in most of the San Diego area (CPUC and BLM 2008). However, there is liquefaction potential in the San Diego Bay and Mission Bay areas near the Rose Canyon Fault zone and other associated faults.

III.4.8.1.2 Los Angeles Area

This transmission corridor extends from Palmdale to the Los Angeles Basin, roughly following segments 6, 7, and 11 of the Tehachapi Renewable Transmission Project (TRTP).

III.4.8.1.2.1 Regional Physiography

The Los Angeles area is located within the Mojave Desert and Transverse ranges geomorphic provinces of Southern California. The area is characterized by a complex series of mountain ranges and valleys with dominant east–west trends. The corridor traverses distinct geographic areas including the Antelope Valley, the Leona Valley (the San Andreas rift zone), the Liebre–Sierra Pelona Mountains, the San Gabriel Mountains, San Gabriel

Valley, and the Montebello and Puente hills. The Antelope Valley consists of approximately 1,200 square miles of elevated desert terrain, located along the western edge of the Mojave Desert. The Leona Valley is a small, northwest–southeast trending longitudinal valley formed by movement on multiple overlapping strands of the San Andreas Fault in the San Andreas rift zone, and in the Los Angeles area is bounded on the northeast by the Portal Hills and on the southwest by the foothills of the Sierra Pelona. The Liebre–Sierra Pelona Mountains are a small northwest–southeast trending mountain range within the central Transverse Ranges. The San Gabriel Mountains are comprised of Precambrian to Cretaceous igneous and metamorphic rock. The San Gabriel Valley is a deep structural basin predominantly filled with semi-consolidated to unconsolidated Quaternary alluvial deposits. The Montebello Hills consist predominantly of Pliocene marine and nonmarine sedimentary rock, whereas the Puente Hills are composed of older (Miocene and Pliocene) marine sedimentary rock (CPUC and USFS 2010).

III.4.8.1.2.2 Geology

The five corridor areas of distinctive geologic character and province are (1) the Antelope Valley, (2) the San Andreas rift zone, (3) the Liebre–Sierra Pelona Mountains, (4) the San Gabriel Mountains, and (5) the Los Angeles Basin. Landforms include lacustrine deposits, alluvial plains and valleys, alluvial fans and pediments, mountain passes, and hills. The route is underlain in various areas by sedimentary, volcanic, igneous, and metamorphic units ranging in age from Quaternary (approximately the last 1.6 million years) to Pre-Cenozoic (greater than 65 million years) (CPUC and USFS 2010).

III.4.8.1.2.3 Soils

The corridor includes undeveloped desert and forest land, agricultural and rural residential land, light industrial and commercial areas, and suburban residential areas.

III.4.8.1.2.4 Slopes

The Los Angeles Area generally does not cross areas with existing landslides. However, mountainous and hilly areas are partially underlain by landslide-prone metamorphic (Pelona Schist and weathered gneiss), sheared igneous and metamorphic (along the San Gabriel Fault), and sedimentary (Puente formation) rocks that are susceptible to slope failures in areas with moderate to steep slopes and unfavorable bedding dip directions. Unmapped landslides and areas of localized slope instability may also be encountered in the hills and mountains. Areas underlain by granitic rocks are generally only susceptible to surficial soil creep, or to rockfall in overly steep areas (CPUC and U.S. Forest Service [USFS] 2010).

III.4.8.1.2.5 Faults and Seismicity

The Los Angeles area is subject to ground shaking earthquakes on multiple strands of the San Andreas Fault system, as well as on the Garlock and other Transverse Ranges faults. Active faults on the San Andreas system are predominantly strike-slip faults with translational movement. Active reverse or thrust faults in the Transverse Ranges include blind thrust faults, responsible for the 1987 Whittier Narrows and the 1994 Northridge earthquakes, and the range-front faults responsible for uplift of the Santa Susana and San Gabriel mountains. The Transverse Ranges fault system consists primarily of blind, reverse, and thrust faults that cause tectonic compressional stresses in the region. Blind faults have no surface expression and have been located with subsurface geologic and geophysical methods. This combination of translational and compressional stresses causes diffuse seismicity across the region (CPUC and USFS 2010).

III.4.8.1.2.6 Liquefaction

Portions of the corridor would meet the criteria for liquefaction in areas underlain by young alluvial deposits including areas in the Leona Valley, the San Gabriel Valley, and in the alluvial and creek deposits of intervening drainages. Older consolidated sedimentary deposits, fine- or coarse-grained deposits, and/or well-drained sedimentary materials are less susceptible to liquefaction (CPUC and USFS 2010).

III.4.8.1.3 Central Valley

This transmission corridor extends from Rosamond in the northern Mojave Desert to Tracy, roughly following the existing Path 15 and 26 corridors. For discussion of geology and soils in the southern portion in the Western Mojave, please refer to the Los Angeles Area in Section III.4.8.1.2.

III.4.8.1.3.1 Regional Physiography

The Central Valley area is located along the boundary between the San Joaquin Valley on the east and the Diablo Range on the west. The San Joaquin Valley comprises the southern half of California's Central Valley geomorphic province, while the Diablo Range is part of the Coast Ranges geomorphic province. The Coast Ranges extend along the California coast from the Santa Ynez River in the south to the Klamath Range in the north.

The topography is varied, with low-rolling to moderately steep slopes in the foothills of the Diablo Range and gentle to nearly level slopes on the alluvial fans and the valley floor. Elevations in the Central Valley area range from about 175 feet in the valleys to over 1,200 feet along some ridges in the foothills.

The Diablo Range is a series of low ridges with elevations of up to 3,000 feet. These mountains form a natural barrier against the coastal winds and fogs, creating a rain shadow effect on the western side of the valley. Numerous intermittent drainages such as the Panoche, Little Panoche, Arroyo Hondo, Cantua, Silver, Domengine, and Los Gatos creeks drain the eastern slopes of the Diablo Range. These creeks have a variable discharge, with periodic flooding that flushes sediments out of the mountains and foothills and deposits them on alluvial fans at the base of the foothills. Recent alluvial fan deposits may extend up to several miles into the valley, with larger, more extensive fans at the mouths of the larger drainages (CPUC 2001).

III.4.8.1.3.2 Geology

The Cretaceous sequence consists of both marine and nonmarine sediments that were laid down in near horizontal beds and have subsequently been uplifted, tilted, folded, and faulted over a long period of time to form the rocks of the eastern foothills of the Diablo Range. The Great Valley sequence is a grouping of sedimentary rocks that formed in the tectonic setting of a forearc basin, adjacent to a subduction zone. These rocks generally consist of well-indurated graywacke sandstone, siltstone, shale, and conglomerates. In the Plan Area, these rocks have been subdivided into the Panoche Formation and the Moreno Shale. The Great Valley sequence overlies rocks of the Franciscan complex, which consists of igneous and sedimentary rocks that have been folded, faulted, and partially metamorphosed, then uplifted onto the continental margin. Paleocene through Miocene marine sediments and Pliocene through Quaternary marine and nonmarine sediments overlie the Cretaceous sequence (CPUC 2001).

III.4.8.1.3.3 Soils

More than 24 different soil series and more than 100 soil types are present in the Central Valley Area. However, the predominant soil series are the Kettleman, Panoche, and Los Banos series, which make up over 90% of the soils:

- **Kettleman Series.** Soils of the Kettleman series have formed in place from the underlying soft sedimentary deposits in the foothills or upland areas. Most of the soils in this series consist of loam and clay loam—with minor fine sandy loam—and have good-to-excessive drainage.
- **Los Banos Series.** Soils of the Los Banos series are primarily developed on terrace deposits derived from weathering and erosion of older sedimentary rocks. They are found in the northern end of the Central Valley area.
- **Panoche Series.** The Panoche series soils are developed on recently deposited alluvial fan materials. The series contains a wide range of soil types, varying from sandy loam to silty clay, with loam and clay-loam the dominant types (CPUC 2001).

III.4.8.1.3.4 Faults and Seismicity

The faults in the Los Banos–Coalinga area were formed by the interaction between the Pacific and North American tectonic plates. Under the current tectonic regime, the Pacific Plate moves northwestward relative to the North American Plate. The primary right lateral, strike-slip faults of the San Andreas fault system cause most of the relative motion of the tectonic plates. In addition, numerous minor faults and folds cause a smaller portion of the crustal strain. The most notable of these faults are the Ortigalita, Quien Sabe, Nunez, and O'Neill fault systems, in addition to the blind thrust faults associated with the Coast Range–Central Valley geomorphic boundary.

Based on historic seismicity, the Central Valley area may be subject to peak ground accelerations of 1.0 g or greater from nearby earthquakes on the San Andreas fault, as well as segments 8 through 13 of the Great Valley blind thrust faults (CPUC 2001).

III.4.8.1.4 Rialto/Moreno Valley/Devers Area

This transmission corridor extends from Devers Substation near Palm Springs to Rialto in San Bernardino County, which roughly follows the existing Devers–Palo Verde No. 2 corridor.

III.4.8.1.4.1 Regional Physiography

The Rialto/Moreno Valley/Devers Area is near the junction of three major physiographic provinces: the Colorado Desert, the northern edge of the Peninsular Ranges, and the Transverse Ranges. The region is geologically complex with a variety of rock types, faults, and geologic features. The corridor skirts the edges of fault-bounded mountain ranges and crosses desert features including badlands (i.e., barren dissected and eroded hills and gullies formed in semi-arid regions with sparse vegetation and high rates of erosion, usually formed in areas underlain by soft or weakly cemented fine-grained geologic units), sand dunes, alluvial fans and pediments, and broad desert valleys dissected by numerous arroyos and washes. Mountains in the Transverse Ranges are generally east–west trending and in the Plan Area include the San Bernardino, Little San Bernardino, Cottonwood, and Indio hills. The Peninsula Ranges are a northwest trending set of fault-bounded mountains and valleys south of the Transverse Ranges, and in the Plan Area include the northern end of the San Jacinto Mountains and the hills known as the San Timoteo Badlands. The Colorado Desert region lies mostly at a low elevation and consists of desert basins with interspersed north-west trending mountain ranges. In the Colorado Desert, the corridor traverses several valleys including the Chuckwalla and Coachella desert valleys and the Palo Verde Valley, which is a river valley of the Colorado River. The proposed route skirts the edge of several mountain ranges, including the Chuckwalla, the Orocopia, and the Mecca Hills (CPUC and BLM 2006).

III.4.8.1.4.2 Geology

The Rialto/Moreno Valley/Devers area crosses alluvial plains and valleys, alluvial fans and pediments, mountain passes, and hills. Geologic materials, in chronologic order, include (1) recent sand dune and recent alluvium (Holocene), (2) nonmarine sedimentary deposits (Pleistocene), (3) marine sedimentary rocks (Eocene), (4) granitic rocks (Mesozoic), (5) granitic and metamorphic rocks (Pre-Cenozoic), and (6) gneiss (Precambrian) (CPUC and BLM 2006).

III.4.8.1.4.3 Soils

The soils along the Rialto/Moreno Valley/Devers area route reflect the underlying rock type, the extent of rock weathering, the degree of slope, and the degree of human modification. Most of the route crosses undeveloped land, although small portions traverse agricultural and rural residential lands.

III.4.8.1.4.4 Slopes

Most of the corridor does not cross areas with existing landslides. However, unmapped landslides and areas of localized slope instability may be encountered in the hills (CPUC and BLM 2006).

III.4.8.1.4.5 Faults and Seismicity

The most significant faults in the Rialto/Moreno Valley/Devers area are faults in the San Andreas fault zone. The San Jacinto fault also crosses just east of Moreno Valley. The San Andreas fault zone is a 680-mile active right-lateral strike-slip complex of faults that has historically caused many of the damaging earthquakes in Southern California. The Coachella segment of the San Andreas fault extends from Cajon Pass (near Bakersfield) to the Salton Sea. Historically, the San Andreas Fault has produced “great” earthquakes that have caused significant surface rupture in Southern California, such as the magnitude 8 January 9, 1857 Fort Tejon earthquake. Surface rupture associated with this earthquake originated northwest of Parkfield in Monterey County and propagated southeastward for over 225 miles along the San Andreas Fault to the Cajon Pass northwest of San Bernardino. The historically seismically dormant (at least since 1769) fault may have an average interval of approximately 145 years between major recurrent earthquakes on its southern segment (CPUC and BLM 2006).

III.4.8.1.4.6 Liquefaction

Due to the generally deep water table (with the exception of the area immediately adjacent to the Colorado River), liquefaction is not considered a potential hazard for most of the corridor (CPUC and BLM 2006).

III.4.8.2 Bureau of Land Management Land Use Plan Amendment Decisions Outside Plan Area

The BLM LUPA decisions affecting soils and geology extend to all BLM-administered California Desert Conservation Area (CDCA) lands, including those outside of the Plan Area. Geologic hazards and soils of concern in the portion of the CDCA that is outside of the Plan Area contain similar desert environments to the affected environment within the Plan Area. This area is considered to have a similar set of resources and hazards as those defined in Sections III.4.2, III.4.3, and III.4.4 for the entire Plan Area.

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