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## Geology, Soils, Paleontology, and Mineral Resources

This section evaluates the potential for implementation of the proposed CalVTP to affect geology, soils, paleontology, and mineral resources. It summarizes the existing regulatory setting and environmental conditions within the treatable landscape using geomorphic provinces delineated by the California Geological Society (CGS). Potential impacts due the implementation of the proposed CalVTP are analyzed, and mitigation measures are provided if those impacts are determined to be significant or potentially significant.

Information used in this section includes the Natural Resources Conservation Service (NRCS) soil survey data, the U.S. Geological Survey maps and reports, scientific studies, CAL FIRE reports, and other technical reports.

Comments on the Notice of Preparation related to geology, soils, paleontology, and mineral resources included concerns about erosion and general soil stability (see Appendix A). These are addressed in the Soil Hazard section of 3.7.1, “Environmental Setting,” and in Impacts GEO-1 and GEO-2.

### Environmental Setting

The potentially affected area with respect to geology, soils, paleontology, and minerals is the geophysical subsurface of the treatable landscape. Geology and soils influence the types of vegetation that can grow in an area which affects the type of vegetation treatments that could occur. Additionally, geology determines topography and the location of rock outcrops to which fuel breaks are often tailored. The environmental setting is described in terms of California’s geomorphic provinces, tectonic setting, topography, soils, and geologic and soil hazards. For the reasons explained below under Issues Not Evaluated Further, mineral and paleontological resources, and some soil hazards (lateral spreading, subsidence, liquefaction, collapse, or expansion) are not described in detail in the environmental setting.

Treatments occur within the treatable landscape and sometimes may result in geologic hazards, such as erosion. Treatment activities currently occur within the treatable landscape and are occasionally visible to public viewers. As described in Chapter 1, “Introduction,” and Section 2.3.1, “Past and Current Treatments,” vegetation treatment currently occurs around the state under several other wildfire risk reduction programs implemented by various federal, state, and local agencies. In 2017–2018, CAL FIRE treated approximately 33,000 acres in California using the same treatment activities as proposed under the CalVTP.

#### Geomorphic Provinces

Organizing the environmental setting into discrete regions that share general geologic and topographic characteristics aids in understanding California’s diverse geology and soils within the treatable landscape. A close association exists between physiographic areas and geology in many parts of California, and in general, large contiguous areas of the state have distinctive features not shared by the adjacent terrain. These large physiographic-geologic areas have been designated “geomorphic provinces” by the CGS and are based on geology, faults, topographic relief, and climate (CGS 2002). California is divided into eleven geomorphic provinces: Great Valley, Sierra Nevada, Cascade Range, Modoc Plateau, Klamath Mountains, Transverse Ranges, Coast Ranges, Peninsula Ranges, Basin and Range, Mojave Desert, and the Colorado Desert (Figure 3.7-1).

The following section and Table 3.7-1 provide general information on the specific characteristics pertaining to each geomorphic province, including characteristic rock types, tectonic setting, topography, and treatable landscape. Geology and topography are closely linked by relationships between rock uplift rates, rock erodibility, and landscape form over geologic time. Rocks, which are the parent material for soil, also affect soil characteristics through variability in infiltration capacity and soil hydraulic conductivity due to differing proportions of sand, silt, and clay (Montgomery and Bolton 2003).



Source: Data downloaded from the California Geological Survey in 2019

Figure 3.7-1 Geomorphic Provinces

Table 3.7-1 Geomorphic Provinces of California and Their Active Faults, Topographic Setting, and Dominant Rock Type

| Geomorphic Provinces | Active Faults (Tectonic Setting) | Topographic Relief | Dominant Rock Type | Treatable Landscape area (acres)1 |
| --- | --- | --- | --- | --- |
| Basin and Range | Death Valley  Deep Springs  Fort Sage  Garlock  Hilton Creek and related  Honey Lake  Little Lake  Northern Death Valley  Owens Valley  Panamint Valley  Sierra Nevada fault zone  Surprise Valley  White Mountains  **(Moderate to High)** | Rugged desert country with high topographic relief. Extension and crustal spreading produce characteristic north-south trending down dropped basins and uplifted ranges. (Low to High) | Sedimentary igneous | WUI: 153,169  Fuel Break: 102,257  Ecological Restoration: 270,736  Total Area2: 467,111 (4.6% of province) |
| Colorado Desert | Brawley  Imperial  San Andreas  Superstition Hills  **(High)** | Depressed low-lying basin. (Low) | Sedimentary | WUI: 334  Fuel Break: 3,477  Ecological Restoration: 3,399  Total Area2: 6,174 (0.3% of province) |
| Cascade Range | Cedar Mountain  Hat Creek  McArthur  **(High)** | Volcanic peaks with deeply incised rivers. (High) | Volcanic | WUI: 412,332  Fuel Break: 251,101  Ecological Restoration: 1,033,048  Total Area2: 1,486,889 (42% of province) |
| Coast Range | Bartlett Springs  Buena Vista  Calaveras  Concord  Green Valley  Greenville  Hayward  Hunting Creek  Little Salmon  Hayward  Hunting Creek  Little Salmon  Los Alamos  Los Osos  Nunez  Ortigalita  Plieto  Rodgers Ck-Healdsburg  San Andreas  San Gregorio  San Simeon  Wheeler Ridge  **(Moderate to High)** | Northwest trending rugged mountainous ranges and valleys; coastal. (Moderate to High) | Partially metamorphosed and fractured volcanic and sedimentary rocks | WUI: 3,795,098  Fuel Break: 1,213,764  Ecological Restoration: 3,623,269  Total Area2: 7,913,153 (41% of province) |
| Modoc Plateau | Cedar Mountain  Hat Creek  McArthur  **(Low)** | Low relief plateau **(Low to Moderate)** | Basalt | WUI: 105,156  Fuel Break: 144,814  Ecological Restoration: 973,701  Total Area2: 1,091,522 (25% of province) |
| Great Valley | Buena Vista  Kern Front  Plieto  Wheeler Ridge  White Wolf  **(Low)** | Nearly flat alluvial plain (Low) | Sedimentary | WUI: 1,096,970  Fuel Break: 308,903  Ecological Restoration: 241,260  Total Area2: 1,478,270 (11% of province) |
| Klamath Mountains | No Major Faults (numerous Quaternary and pre-Quaternary faults)  **(Moderate)** | Rugged steep slopes **(High)** | Low to high grade metamorphosed sedimentary rocks with intrusive plutonic rocks | WUI: 328,879  Fuel Break: 137,550  Ecological Restoration: 911,453  Total Area2: 1,259,635 (22% of province) |
| Mojave Desert | Burnt Mountain  Calico  Eureka Peak  Garlock  Helendale  Kickapoo  Lenwood  Manix  Mesquite Lake  Newberry fracture zone  North Frontal  Pinto Mountain  Pisgah-Bullion  Johnson Valley  **(High)** | Isolated mountains with large expanses of desert plains**. (Low to Moderate)** | Sedimentary  Volcanic | WUI: 147,599  Fuel Break: 75,365  Ecological Restoration: 20,785  Total Area2: 217,114 (1.4% of province) |
| Peninsular Ranges | Elsinore  Newport-Inglewood  Rose Canyon  San Jacinto  Whittier  **(Moderate to High)** | Higher mountains and long valleys, often hilly in nature. **(High)** | Igneous (granite) | WUI: 891,802  Fuel Break: 251,370  Ecological Restoration: 277,595  Total Area2: 1,240,826 (22% of province) |
| Sierra Nevada | Cleveland Hill  Fort Sage  Garlock  Hilton Creek  Honey Lake  Kern front  Little Lake  Owens Valley  Sierra Nevada fault zone  White Wolf  **(Moderate)** | Tilted fault block with high rugged scarps. In many areas shaped by tectonic uplift (mountain building) and glacial processes (erosion). **(High)** | Igneous (granite) | WUI: 2,483,905  Fuel Break: 470,263  Ecological Restoration: 1,634,619  Total Area2: 4,217,450 (26% of province) |
| Transverse Ranges | Cucamonga  Los Alamos  Malibu  North Frontal  Pinto Mountain  Raymond Hill  Red Mountain  San Andreas  San Cayentano  San Fernando  San Gabriel  Ventura  **(Moderate to High)** | High rugged mountains, with long narrow valleys. **(High)** | Sedimentary  Igneous | WUI: 638,713  Fuel Break: 169,894  Ecological Restoration: 204,268  Total Area2: 880,169 (24% of province) |

1. Wildland Urban Interface (WUI), Fuel B~~b~~reak, and Ecological Restoration are described in Chapter 2, “Program Description”

2 Total area is not the sum of the three treatment types because there is overlap between the modeled treatment types. Total area is extent of the treatable landscape and does not account for overlap of treatment types.

Sources: CGS 2002, Sutch and Dirth 2003

##### Basin and Range

The Basin and Range geomorphic province is characterized by roughly parallel, fault-bounded mountain ranges separated by down-dropped basins formed in response to crustal thinning and extension (CGS and CSP 2015). The Basin and Range province is a large region of alternating north-south trending faulted mountains and valley floors that encompasses the majority of the western U.S, including portions of southern Oregon, eastern California, southern portions of Arizona and New Mexico, western Texas, and the majority of Nevada. Death Valley, the lowest area in the United States (280 feet below sea level), is one of these basins (CGS 2002). Within California, the lowest point is 282 feet below sea level in Death Valley and the highest elevation is 14,252 feet above sea level at White Mountain Peak (CGS 2002). California’s portion of the Basin and Range province includes three separate physiographic areas. The northernmost portion of the province is bounded by the Modoc Plateau province and the Nevada border. The middle portion of the province is bounded to the north by the Modoc Plateau province and to the south by the Sierra Nevada province. The largest and southernmost portion of the province is bounded on the west by the Sierra Nevada province, to the south by the Mojave Desert province, and to the east by the Nevada border. The Basin and Range province is cut off abruptly by the Garlock fault to the south. The treatable landscape of the Basin and Range consists of only 4.6 percent of the province. In the southern portion, the treatable landscape mostly includes area on the west side of the province near Bishop and in the Owens River Gorge. The treatable landscape in the central portion of the province includes mostly the mountain ranges south and east of Susanville and the mountainous area near the state line. The northern portion includes mostly the lower basin areas.

##### Cascade Range

The Cascade Range, a chain of volcanic cones, extends through Washington and Oregon into California. In California, the range is dominated by Mt. Shasta, a glacier-mantled volcanic cone, rising 14,162 feet above sea level. The Cascade Range is part of the Pacific Ring of Fire, a nearly continuous arc of intense seismicity and volcanoes around the Pacific Ocean. The southern termination of the Cascade Range is Lassen Peak, which last erupted in the early 1900s (CGS 2002). The Cascade Range is transected by deep canyons of the Pit River. The river flows through the Range between these two major volcanic cones, after winding across interior Modoc Plateau on its way to the Sacramento River (CGS 2002). The California portion of the Cascade Range province is located between the Klamath Mountains province to the west and the Modoc Plateau province to the east, and extends south from the Oregon border to the Great Valley and Sierra Nevada provinces. The northern part of the Cascade Range in California is divided into the Western Cascade Range and the High Cascade Range. The Western Cascades are composed of eroded Oligocene to Pliocene volcanic and volcaniclastic rocks overlying older Upper Cretaceous and Eocene sedimentary rocks. The volcanic rocks of the Western Cascade were faulted and tilted eastward and northeastward in the Late Miocene (du Bray et al. 2006). Erosion of the steep volcanic landforms of the Western Cascade Range reduced the region to gentle rolling hills before renewed volcanism built the High Cascade Range. All of the volcanoes of the Cascade Range and Modoc Plateau region are geologically young, and it is likely that there will be future eruptions in the region (DeCourten 2009). The Cascade Range contains the most treatable landscape area of any geomorphic province (42 percent). The treatable landscape includes both mountainous and lower lying areas. The major volcanoes (Shasta and Lassen) are excluded from the treatable landscape.

##### Coastal Ranges

The Coastal Ranges physiographic province extends more than 370 miles from the Transverse Ranges in the south to beyond the Oregon border in the north (DeCourten 2009). The coastal mountains in this province are all aligned in a consistent northwest trend. The Coast Ranges are generally oriented parallel to the Great Valley and Sierra Nevada provinces to the east and have a similar extent. The relatively recent emergence of the Coast Ranges was strongly affected by the evolution of the San Andreas fault system and the development of the modern transform boundary between the Pacific and North American plates (DeCourten 2009). The California Coast Ranges have traditionally been divided into northern and southern portions with the San Francisco Bay dividing the two. However, it is more meaningful to divide the Coast Ranges into northern and southern portions separated by the San Andreas fault system. The California Coast Ranges are primarily composed of Jurassic- to Cretaceous-age (about 65-150 million years old) marine sedimentary and volcanic rocks of the Franciscan assemblage. The Franciscan assemblage consists of partially metamorphosed greenstone, basalt, chert, and graywacke that originated as sea floor sediments. The coastline along this province is uplifted, wave-cut, and terraced. The eastern border of the Coast Ranges province is characterized by ridges and valleys in Mesozoic strata (CGS 2002). The Coastal Ranges contain the second largest treatable landscape of the geomorphic provinces (41 percent). The treatable landscape consists of a wide range of topography and the only larger excluded areas are populated areas and National Forest lands.

##### Colorado Desert

The Colorado Desert province is located to the east of the Peninsular Ranges province and west of the Mojave Desert province. Part of the boundary on the north is formed by the eastern Transverse Ranges. The eastern boundary runs along the Little San Bernardino, Orocopia, and Chocolate Mountains. The Colorado River runs through the extreme southeast corner of the province. Elevations throughout the province are low and extend below sea level in the valley bottoms. The province is a depressed block between active branches of alluvium-covered San Andreas Fault with the southern extension of the Mojave Desert on the east (CGS 2002). The Salton Trough, a northwest trending basin located completely within the province, is the largest area below sea level in the Western Hemisphere. The trough is being created due to crustal spreading. The Salton Sea, the largest lake in California, is located within the Salton trough and receives drainage from the Coachella Valley to the north and the Imperial Valley to the south. The crust beneath the Salton Sea is 10.5 miles thick, about 6 miles thinner than continental crust in other areas and is seismically active (Han et al. 2016). The Salton Trough was filled intermittently with the large ancient Cahuilla Lake during the Pleistocene. The treatable area within the Colorado Desert is the smallest of any geomorphic province (0.3 percent) and includes only small area near the western border near Ocotillo.

##### Great Valley

The Great Valley of California, also called the Central Valley of California or the San Joaquin-Sacramento Valley, is a nearly flat alluvial plain extending from the Tehachapi Mountains on the south to the Klamath Mountains to the north, and from the Sierra Nevada to the east to the Coast Ranges to the west. Elevations of the alluvial plain are nearly 300 feet above sea level, with extremes ranging from a few feet below sea level to about 1,000 feet above sea level (CGS 2002). The only prominent topographic feature within the central part of the valley is the Marysville (Sutter) buttes, a Pliocene volcanic plug that abruptly rises 2,000 feet above the surrounding valley floor. Geologically, the Great Valley is a large elongate northwest-trending asymmetric structural trough that has been filled with tremendously thick sequences of sediments ranging in age from Jurassic to Recent (CGS 2002). The northern part of the Valley is drained by the Sacramento River and its southern part is drained by the San Joaquin River. The basin has a regional southward tilt and is cut by two significant cross-valley faults. The northernmost fault, the Stockton fault, is the boundary used by most geologists to separate the Great Valley Basin into the Sacramento and San Joaquin River basins. The other great cross-fault lies near the southern end of the basin and is named the White Wolf fault. Only 11 percent of this province is treatable landscape and all of this area is located near the borders of other geomorphic provinces. This includes the foothills of the Sierra Nevada and Coastal Ranges.

##### Klamath Mountains

The Klamath Mountains province is considered to be a northern extension of the Sierra Nevada (CGS 2002). The Klamath Mountains shares with the Sierra Nevada a long history of subduction where one tectonic plate slides under another plate. As this occurs, land forms on the subducting plate are scraped off the top of the plate and get attached to the overriding plate. This process began in the Paleozoic Era during which numerous oceanic terranes collided with the western edge of North America (DeCourten 2009). The oceanic rocks and serpentinite of the Klamath Mountains represent land forms that were attached to the overriding plate during subduction. The land forms have had magma flow into them where there are areas of weakness between rocks. Studies that dated rocks in the province show the terranes are progressively younger from east to west, ranging from Devonian to Late Jurassic Periods (416 to 190 million years ago) (CGS 2015). Unlike most other geologic provinces in northern California, the Klamath Mountains lack a prominent northwest orientation. They have rugged topography with prominent peaks and ridges reaching 6,000–8,000 feet above sea level. This elevated terrain is deeply incised by the Klamath River and its tributaries (DeCourten 2009). The treatable landscape includes 22 percent of this province mostly on the east side in mountainous terrain.

##### Modoc Plateau

The Modoc Plateau consists of a thick accumulation of lava flows and tuff beds along with many small volcanic cones. Occasional lakes, marshes, and streams meander across the plateau. The plateau is cut by many north south faults. The province is bound indefinitely by the Cascade Range on the west and the Basin and Range on the east and south. The Modoc Plateau consists of a series of northwest to north-trending block-faulted ranges, with intervening basins filled with broad-spreading “plateau” basalt flows, or with small shield volcanoes, steeper sided lava or composite cones, cinder cones, and lake deposits resulting from disruption of the drainage by faulting or volcanism (MacDonald 1966). The Modoc Plateau contains an expanse of lava flows at an altitude of 4,000 to 6,000 feet and is considered a part of the western extent of the Great Basin that was flooded by volcanics related to the Cascade Range volcanics (MacDonald 1966). The Modoc Plateau treatable landscape consists of 25 percent of the province mostly in areas of higher elevation.

##### Mojave Desert

The Mojave Desert Province is a broad interior region isolated by mountain ranges separated by expanses of desert plain (CGS 2002). Valley bottoms range in elevation from 2,000-4,000 above sea level and mountains range between 3,500 and 5,000 feet. The highest elevation in the province is 7,929 feet at Clark Mountain (Sutch and Dirth 2003). The province is situated in the southeastern corner of California and bordered by the Basin and Range province and the Sierra Nevada province to the north, and the Transverse Ranges province and the Colorado Desert provinces to the southwest (Sutch and Dirth 2003). In relation to tectonics, the Mojave Desert is bordered by the Garlock fault to the north, the San Andreas Fault to the southwest, and the southern extension of the Death Valley fault zone to the east (CGS 2002). Rocks of Precambrian to late Cenozoic age are exposed across the greater Mojave Desert Province region. The area forms the southeastern extent of the Precambrian continental North America (Martin and Walker 1992). There is very little treatable landscape (1.4 percent) within the Mojave Desert province. The treatable landscape is located on the western side of the province on alluvial fans draining the Transverse Ranges and the southern Sierra Nevada.

##### Peninsular Ranges

The Peninsular Ranges province consists of southeast-northwest trending ranges separated by long valleys that run sub-parallel to faults branching from the San Andreas Fault (CGS 2002). The trend of topography is similar to the Coast Ranges, but the geology is more like the Sierra Nevada (CGS 2002). The Peninsular Ranges merge northward into the Los Angeles Basin, where their northwest trend eventually terminates against the east-west trending Transverse Ranges Province. The Peninsular Ranges province is bounded by the Transverse Ranges province to the north, the Colorado Desert province to the east, and the Mexico border to the south. Westward, the province does not end at the Pacific shore, but continues far out under the ocean as a broad submerged continental shelf. The treatable landscape in the Peninsular Ranges includes 22 percent of the province. The treatable area is mostly located within mountainous areas set back from the coast with two exceptions near Laguna Beach and Encinitas.

##### Sierra Nevada

The Sierra Nevada is a strongly asymmetric mountain range with a long gentle western slope, and a high and steep eastern escarpment. It is 50 to 80 miles wide and runs northward through eastern California for more than 400 miles, from the Mojave Desert in the south to the Cascade Range in the north. The topography of the Sierra Nevada is shaped by uplift and glacial action. The Sierra Nevada is a huge block of the earth’s crust that has broken free on the east along the Sierra Nevada fault system and been tilted westward. It is overlapped on the west by sedimentary rocks of the Great Valley and on the north by volcanic sheets extending south from the Cascade Range. A blanket of volcanic material caps large areas in the northern part of the range. Most of the south half of the Sierra Nevada and the eastern part of the northern half are composed of plutonic (chiefly granitic) rocks of the Mesozoic age (DeCourten 2009). These rocks comprise the Sierra Nevada batholith, a part of an early continuous belt of plutonic rocks that extend from Baja California northward through the Peninsular Ranges and the Mojave Desert. The Sierra Nevada batholith represents the deep roots of a Mesozoic volcanic arcthat developed along the western margin of North America above the Farallon subduction zone. Eroded material from the Sierra Nevada helps sustain the fertility of California’s rich agricultural soils (DeCourten 2009). The treatable landscape includes 26 percent of the Sierra Nevada geomorphic province. This area is mostly located on the western slope in the foothills but also includes mountainous areas to the east in the northern portion of the province.

##### Transverse Ranges

The Transverse Ranges province averages 30 miles long and is nearly 300 miles wide, extending from Point Arguello eastward to the Eagle Mountains in the Colorado Desert (Sharp 1994). Mountains in the Transverse Ranges province are composed of progressively older rocks from the west to the east (Sutch and Dirth 2003). The east-west trending landscape defines the Transverse Ranges province, so named because structurally, the geologic features of this province are crosswise to the usual north-westerly trend of California topography. This characteristic is established by faults and folds that control the trend and shape of the mountains, valleys and coastline. Intense north-south compression is squeezing the Transverse Ranges (CGS 2002). As a result, this is one of the most rapidly rising regions on earth (CGS 2002). Sedimentary rocks predominate in the west and older igneous and metamorphic rocks predominate in the east (Sharp 1994). One of the largest pre-historic landslides in the nation, the Blackhawk landslide, is found within this province. This landslide is located on the north side of the San Bernardino Mountains and is five miles long and two miles wide and up to 100 feet thick. The volume of the landslide is estimated to be 370 million cubic yards in size (Sutch and Dirth 2003). The treatable landscape area includes 24 percent of the province and includes mostly mountainous terrain that is located near populated areas.

#### Tectonic Setting (Faulting and Seismicity)

The large-scale processes that move and deform the earth’s crust are referred to as plate tectonics. The earth’s outer layers consist of a number of rigid plates that are mobile, and the boundaries of the plates cause many of earth’s deformation events (Harden 1997). California has been at an active plate boundary for 230 million years and this has been the dominant factor in California geologic history (Harden 1997). Tectonic deformation causes fractures in the upper crust and fragments bedrock into debris that is more easily weathered by surface processes (Molnar et al. 2007). Table 3.7 1 below characterizes the tectonic setting for the various geomorphic provinces. A designation of “low” indicates that tectonic activity is relatively infrequent in that province, whereas “high” indicates that tectonic activity has resulted in seismic activity, relatively high relief, and/or large scale weakening of earth materials. Provinces with active faults generally have high tectonic activity.

The lowest tectonic activity in California is associated with the Great Valley and Modoc Plateau geomorphic provinces. The tectonic setting of the Great Valley is one of a forearc basin situated between the Sierran arc and the Mesozoic subduction zone, whereas the Modoc Plateau has been subject to crustal extension (Harden 1997). The Sierra Nevada and Klamath Mountains geomorphic provinces display moderate tectonic activity. The Sierra Nevada is the recently uplifted remains of an ancient volcanic arc formed by Mesozoic subduction and accretion. The Klamath Mountains province is a result of Mesozoic subduction, accretion, and intrusion of granitic plutons (Harden 1997). Moderate to high levels of tectonic activity are present in the Transverse Ranges, Basin and Range, Peninsular Ranges, and Coast Ranges geomorphic provinces. The Transverse Ranges are presently subjected to transform plate motion and strike-slip shearing. The left-stepping bend in the San Andreas Fault has resulted in compressional forces causing some of the highest rates of uplift in the world (Harden 1997). The Basin and Range province has been subjected to crustal extension for the past 22 million years (Harden 1997) and has been subject to strong earthquakes. The Peninsular Ranges are currently subject to transform faulting and are also subject to uplift (Lewis et al. 2001). The Coast Ranges have a complex tectonic history of Mesozoic subduction and accretion, as well as Cenozoic transform plate motion associated with the San Andreas Fault. Some of highest levels of tectonic activity are associated with crustal extension in the Colorado Desert geomorphic province. This tectonic activity has resulted in features such as the Salton Trough, a pull-apart sedimentary basin that has also experienced relatively recent volcanism. The Mojave Desert province is bounded on the west by the San Andreas Fault and the north by the Garlock Fault, and has also been subjected to stretching of the crust and recent volcanism. The Cascade Range geomorphic province is associated with active subduction along the Cascadia subduction zone. Active subduction has resulted in volcanic cone formation, with the elevation of Mount Shasta exceeding 14,000 feet. High levels of tectonic activity are also associated with portions of the Coast Ranges proximal to the Mendocino Triple Junction. This portion of the Coast Ranges has been subjected to extensive deformation, crustal thickening, and relief production (Furlong and Govers 1999).

#### Topography

The topography of California is highly varied from 282 feet below sea level in Death Valley to 14,494 feet at the peak of Mount Whitney. The mean elevation of California is approximately 2,900 feet. Topography has an important influence on geomorphic processes due to its effect on slope, which controls the hydraulic gradient of water flow, the energy of erosive runoff, as well as the driving forces for landsliding (Istanbulluoglu and Bras 2005). Topography is strongly controlled by an area’s tectonic setting (Harden 1997). In Table 3.7-1, a designation of “low” topographic relief means that the geomorphic province has relatively gentle slopes and a province with a characterization of “high” topographic relief has relatively steep slopes.

Geomorphic provinces with low topographic relief include the Colorado Desert and the Great Valley geomorphic provinces. Low to moderate topographic relief exists for the Modoc Plateau and the Mojave Desert geomorphic provinces. Low to high relief is a characteristic of the Basin and Range province, whereas the Coast Ranges province displays moderate to high topographic relief. The highest topographic relief occurs in the Klamath Mountains, Sierra Nevada, and Cascade Ranges geomorphic provinces, where maximum elevations exceed 9,000 to 14,000 feet. The topography of the treatable landscape throughout California is highly varied and includes low lying valleys, foothills, and mountainous regions.

#### SOILS

Soil refers to the unconsolidated, thin, variable layer of mineral and organic material, usually biologically active, that covers most of the earths land surface (Singer and Munns 1999). Soils have structural and biological properties that distinguish them from the rocks and sediment from which they normally originate (Singer and Munns 1999). Soil conditions in California reflect a diversity of geologic, topographic, climatic, temporal, and vegetative conditions that influence soil formation and composition (Jenny 1994). Instead of specific properties that define a regional soil, there is a general gradational transition between the properties of one soil compared to another often resulting in many soil types in a relatively small area. As a result, a regional evaluation of soils beyond inventory data is not informative or useful in the context of the CalVTP PEIR. Rather, a general discussion of soil properties and soil hazards that could affected the CalVTP follows.

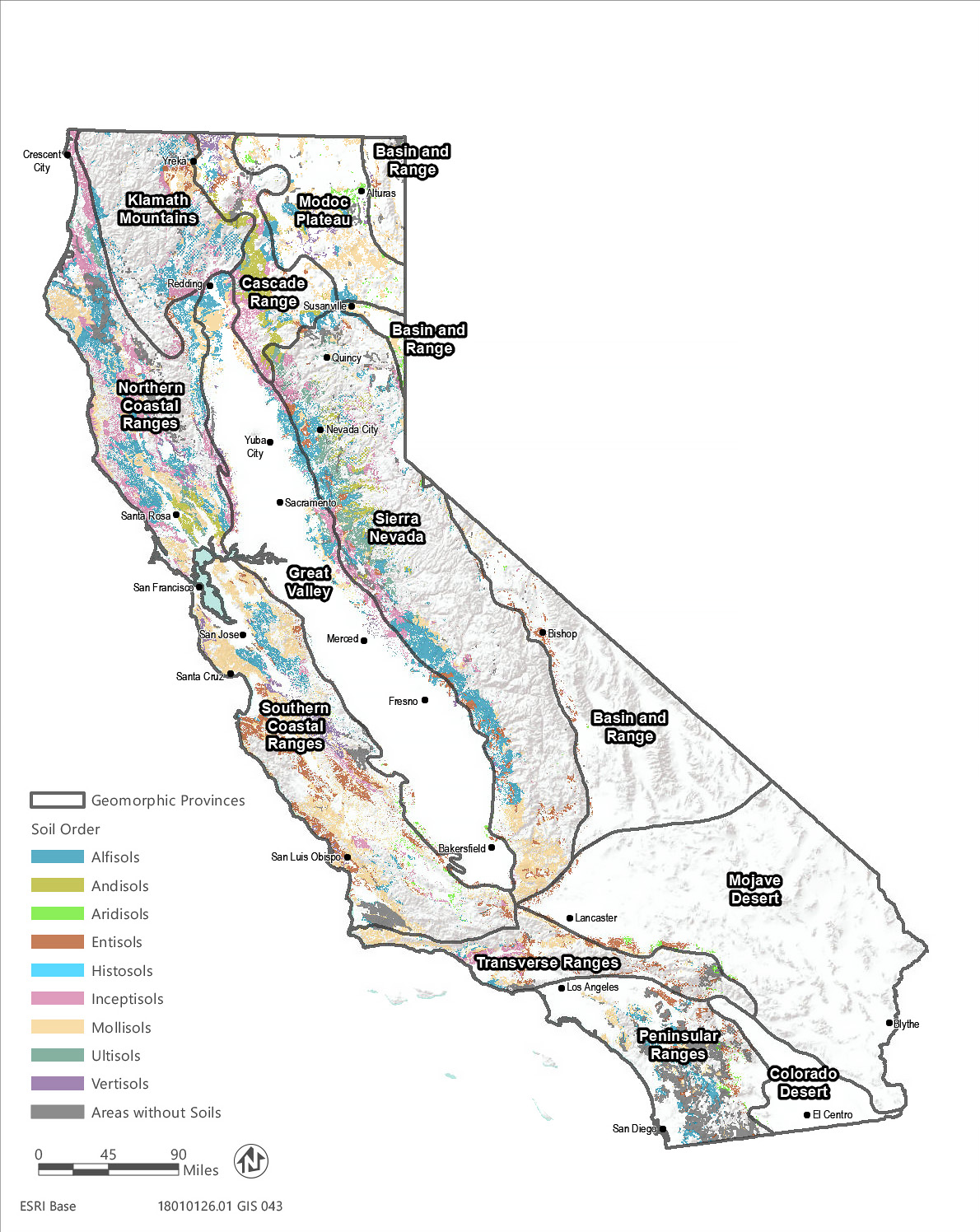
Soils can be classified using a variety of methods depending on the application of the information. Soil scientists typically use classification methods that group soils by their intrinsic properties, geologic origin, and soil behavior in different conditions. The U.S. Department of Agriculture (USDA) NRCS utilizes the USDA soil taxonomy system for the classification of soils. This classification is based on chemical, biological, and physical characteristics of soils, including soil color, texture, structure, mineralogy, salt content, and depth. For this reason, it is the most relevant method to use in classify soils for the CalVTP, especially the soil hazard rating for erosion, mudflow, and landslide potential (see “General Soil Order Descriptions,” below).

##### General Soil Order Descriptions

Soil Order represents the broadest category of soils using the USDA “Soil Taxonomy.” Soil taxonomy is a basic system of soil classification. There are 12 soil orders, differentiated by the presence or absence of diagnostic horizons or layers; these are listed as follows and described below: Alfisols, Andisols, Aridisols, Entisols, Gelisols, Histosols, Inceptisols, Mollisols, Oxisols, Spodosols, Ultisols, and Vertisols. Orders are divided into Suborders and the Suborders are farther divided into Great Groups. Ten of the twelve soil orders can be found in California because conditions necessary for the formation of gelisols (only occur in Alaska (NRCS 2019a) or oxisols (only found on tropical and subtropical islands (NRCS 2019a) do not exist in California; these are briefly described below. As indicated below, more productive soils are more likely to support a robust vegetation community which reduces susceptibility to erosion. Figure 3.7-2 shows where each soil order occurs within the treatable landscape.

* **Entisols:** Entisols have little or no evidence of soil development other than presence of an identifiable topsoil horizon (Soil Science Society 2018). These are considered newly formed soils.
* **Inceptisols:** Inceptisols exhibit a moderate degree of soil development and lack significant clay accumulation in the subsoil. They occur over a wide range of parent materials and climatic conditions, and thus have a wide range of characteristics (Soil Science Society 2018).
* **Vertisols:** Vertisols have a high content of clay that shrink when drying and swell when wet which forms deep wide cracks (Singer and Munns 1999). Vertisols are considered a more productive order of soils.
* **Aridisols:** Aridisols form in very dry regions and are the only order that places climate as the highest level factor for classification (Singer and Munns 1999).
* **Alfisols:** Alfisols are moderately weathered and have accumulations of translocated clay in the subsoil which can hold and supply moisture and nutrients to plants. They are formed primarily under hardwood forest or mixed vegetative cover and are productive for most crops (Soil Science Society 2018). Alfisols are considered a more productive order of soils.
* **Mollisols:** Mollisols are soils with a high surface accumulation of organic matter (Singer and Munns 1999). Mollisols are considered deep and fertile and are a more productive order of soils.
* **Spodosols:** Spodosols are sandy and acidic.They are amorphous mixtures of organic matter and aluminum, with or without iron, have accumulated (Singer and Munns 1999). These soils are usually found in cool humid regions and on coarse textured parent material.
* **Histosols:** Histosols are dominantly decaying plant material in their upper portions (Singer and Munns 1999). They are mostly soils that are commonly called bogs, moors, or peats and mucks.
* **Andisols:** Andisols typically form from the weathering of volcanic materials such as ash, resulting in minerals in the soil with poor crystal structure. These minerals have an unusually high capacity to hold both nutrients and water, making these soils very productive and fertile (Soils Science Society 2018).
* **Ultisols:** Ultisols are weathered soils of warm, wet climates that are highly leached and generally infertile. They contain a subsoil accumulation of clay. Most of these soils supported mixed coniferous and hardwood forest vegetation at the time of settlement. Some are now used as cropland or pasture (NRCS 2019a).

Table 3.7-2 shows the amount (acres or percentage) of each soil order by modeled treatment area for each geomorphic province in the treatable landscape. As stated above, more productive soils are more likely to support a robust vegetation community which reduces susceptibility to erosion. The more productive soil orders (i.e., Alfisols, Andisols, Mollisols, and Vertisols) make up over 30 percent of the treatable landscape within the Basin and Range, Cascade Range, Great Valley (WUI only), Klamath Mountains, Coast Ranges, and Modoc Plateau, Sierra Nevada, and Transverse Ranges (see bolded entries in Table 3.7-2). The arid Colorado Desert (Entisol), Mojave Desert (Entisol), Peninsular Ranges (just under 30 percent in Alfisol), are the geomorphic provinces with the least treatable landscape area in productive orders.



Source: Data downloaded from NRCS in 2019; adapted by Ascent Environmental in 2019

Figure 3.7-2 Soil Orders within the Treatable Landscape

Table 3.7-2 Soil Orders by Treatable Landscape in Each Geomorphic Province

| Geomorphic Provinces | Alfisols  (% of treatable area) | Andisols  (% of treatable area) | Aridisols  (% of treatable area) | Entisols  (% of treatable area) | Histosols  (% of treatable area) | Inceptisols  (% of treatable area) | Mollisols  (% of treatable area) | Ultisols  (% of treatable area) | Vertisols  (% of treatable area) | Total by Province (acres) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Basin and Range | WUI: 8.1%  Fuel Break: 4.8%  Eco: 4.4% | WUI: 0.1%  Fuel Break: 0.01%  Eco: 0 | WUI: 9.4%  Fuel Break: 10.2%  Eco: 13.3% | **WUI: 37.9%**  **Fuel Break: 43.1%**  Eco: 16.4% | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 0.5%  Fuel Break: 2.8%  Eco: 0.9% | **WUI: 43.5%**  **Fuel Break: 34.6%**  **Eco: 55.3%** | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 0  Fuel Break: 0.5%  Eco: 2.6% | WUI: 153,169 (465 blank)  Fuel Break: 102,257 (3,881 blank)  Eco: 270,736 (19,497 blank) |
| Cascade Range | WUI: 15.4%  Fuel Break: 16.0%  Eco: 16.9% | **WUI: 36.8%**  **Fuel Break: 36.9%**  **Eco: 33.9%** | WUI: 0.7%  Fuel Break: 0.4%  Eco: 0.3% | WUI: 4.9%  Fuel Break: 3.8%  Eco: 4.5% | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 21.9%  Fuel Break: 22.2%  Eco: 20.6% | WUI: 7.1%  Fuel Break: 10.8%  Eco: 15% | WUI: 3.9%  Fuel Break: 1.6%  Eco: 0.9% | WUI: 7.1%  Fuel Break: 5.1%  Eco: 5.2% | WUI: 412,332 (9,352 blank)  Fuel Break: 251,096 (8,272 blank)  Eco: 1,033,028 (28,321 blank |
| Colorado Desert | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 0.5%  Fuel Break: 43.5%  Eco: 0 | **WUI: 99.5%**  **Fuel Break: 48.9%**  **Eco: 100%** | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 334  Fuel Break: 3,477 (262 blank)  Eco: 3,399 |
| Great Valley | **WUI: 42.9%**  Fuel Break: 29.5%  Eco: 14.9% | WUI: 0.3%  Fuel Break: 0.2%  Eco: 0.2% | WUI: 0.9%  Fuel Break: 4.8%  Eco: 0.5% | WUI: 5.8%  Fuel Break: 14.6%  Eco: 3.4% | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 21.4%  Fuel Break: 20.5%  **Eco: 44.4%** | WUI: 22.2%  Fuel Break: 22.3%  Eco: 25.6% | WUI: 2.9%  Fuel Break: 0.9%  Eco: 0.5% | WUI: 2.6%  Fuel Break: 6.4%  Eco: 10.1% | WUI: 1,096,970 (11,304 blank)  Fuel Break: 308,903 (2,922 blank)  Eco: 241,260 (1,152 blank) |
| Klamath Mountains | **WUI: 43.3%**  **Fuel Break: 38.4%**  **Eco: 45.5%** | WUI: 2.3%  Fuel Break: 5.1%  Eco: 5.2% | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 13.2%  Fuel Break: 11.4%  Eco: 7.6% | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 19.3%  Fuel Break: 26.1%  Eco: 28.5% | WUI: 20.2%  Fuel Break: 16.9%  Eco: 10.4% | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 0.3%  Fuel Break: 0.1%  Eco: 0.02% | WUI: 328,879 (5,048 blank)  Fuel Break: 137,550 (2,868 blank)  Eco: 911,448 (25,408 blank) |
| Modoc Plateau | WUI: 12.9%  Fuel Break: 19.4%  Eco: 18% | WUI: 4.5%  Fuel Break: 5.8%  Eco: 5.2% | WUI: 20.9%  Fuel Break: 5.5%  Eco: 6.4% | WUI: 1.6%  Fuel Break: 1.2%  Eco: 1.2% | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 0.04%  Fuel Break: 1.0%  Eco: 0.8% | **WUI: 34.3%**  **Fuel Break: 55.6%**  **Eco: 57.9%** | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 23.0%  Fuel Break: 8.9%  Eco: 6.5% | WUI: 105,156 (2,908 blank)  Fuel Break: 144,814 (3,883 blank)  Eco: 973,701 (38,474 blank) |
| Mojave Desert | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 18.2%  Fuel Break: 13.9%  Eco: 0.5% | **WUI: 67.7%**  **Fuel Break: 75.6%**  **Eco: 83.1%** | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 12.7%  Fuel Break: 8.2%  Eco: 15.0% | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 147,599 (1,889 blank)  Fuel Break: 75,365 (1,680 blank)  Eco: 20,785 (289 blank) |
| Coastal Ranges | WUI: 20.1%  Fuel Break: 19.6%  Eco: 26.0% | WUI: 4.1%  Fuel Break: 4.0%  Eco: 0.3% | WUI: 0.4%  Fuel Break: 0  Eco: 0.5% | WUI: 9.6%  Fuel Break: 15.0%  Eco: 12.0% | WUI: 0.01%  Fuel Break: 0.004%  Eco: 0 | **WUI: 18.2%**  Fuel Break: 14.5%  Eco: 20.4% | WUI: 36.7%  Fuel Break: 35.7%  Eco: 28.5% | WUI: 2.9%  Fuel Break: 1.6%  Eco: 2.1% | WUI: 4.2%  Fuel Break: 5.0%  Eco: 4.2% | WUI:3,792,162 (148,763 blank)  Fuel Break: 1,213,572 (56,574 blank)  Eco: 3,622,321 (212,431 blank) |
| Peninsular Ranges | WUI: 24.7%  Fuel Break: 21.5%  Eco: 22.4% | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 1.2%  Fuel Break: 4.7%  Eco: 3.7% | WUI: 11.1%  Fuel Break: 17.9%  Eco: 25.4% | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 15.7%  Fuel Break: 16.3%  Eco: 13.4% | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 891,801 (422,146 blank)  Fuel Break: 251,365 (99,337 blank)  Eco: 277,595 (97,243 blank) |
| Sierra Nevada | **WUI: 37.8%**  **Fuel Break: 33.1%**  **Eco: 30.2%** | WUI: 5.1%  Fuel Break: 8.7%  Eco: 10.2% | WUI: 0.3%  Fuel Break: 1.2%  Eco: 0.4% | WUI: 11.1%  Fuel Break: 10.6%  Eco: 7.1% | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 11.7%  Fuel Break: 12.3%  Eco: 15.7% | WUI: 12.3%  Fuel Break: 19.7%  Eco: 23.1% | WUI: 18.3%  Fuel Break: 11.2%  Eco: 10.2% | WUI: 0.5%  Fuel Break: 0.7%  Eco: 0.1% | WUI: 2,483,903 (73.518 blank)  Fuel Break: 470,263 (12,163 blank)  Eco: 1,634,618 (51,057 blank) |
| Transverse Ranges | WUI: 6.6%  Fuel Break: 7.2%  Eco: 7.1% | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 1.6%  Fuel Break: 1.5%  Eco: 0.8% | WUI: 28.1%  **Fuel Break: 32.4%**  Eco: 20.5% | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 14.8%  Fuel Break: 12.9%  Eco: 20.9% | **WUI: 41.2%**  **Fuel Break: 38.1%**  **Eco: 43.3%** | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 0  Fuel Break: 0  Eco: 0 | WUI: 638,513 (49,111 blank)  Fuel Break: 169,821 (13,238 blank)  Eco: 204,253 (14,982 blank) |

Sources: Compiled by Ascent Environmental in 2019 from data downloaded from NRCS in 2019

#### GEOLOGIC AND SOIL HAZARDS

The CalVTP does not propose any development that would be affected by lateral spreading, subsidence, liquefaction, collapse, or expansion. For this reason, these soil hazards are not discussed further in the document.

##### Landslides

Unstable hillslopes are areas susceptible to landsliding. Landslides consist of the downslope movement of soil and rock under the influence of gravity. The geologic and topographic features of the landscape are the primary determinants of the shear strength of the hillslope materials (i.e., resistance to landslides) and hillslope shear stress (i.e., propensity for landsliding). Landslides occur when the shear stress exceeds the shear strength of the materials forming the slope (Highland and Bobrowsky 2008). Factors contributing to high shear stress on hillslopes include steep slopes, high mass loading (e.g., through high soil moisture levels or placement of fill material), slope undercutting (e.g., through erosion or excavation), and soils that vary in volume (shrink and swell) in relation to moisture content. Factors contributing to low shear strength of hillslope materials include bedding planes that dip in the same direction as the slope at the same or a lesser degree of steepness, high water pressure in soil pores (e.g., saturated soil underlain by a restrictive layer), presence of faults or joints, and weak materials (e.g., soft soils or rock, unconsolidated materials, fine grain size) (Highland and Bobrowsky 2008). Climate and vegetative cover also affect landslide hazard because of their influence on soil root support, which resists landsliding, and hillslope moisture, which drives landsliding (Istanbulluoglu and Bras 2005).

The best indicator of high landslide potential is evidence of previous landsliding (Highland and Bobrowsky 2008). Landslides can be classified as active or dormant, based on how recently they have moved. Active landslides typically display cracks or sharp, bare scarps. Vegetation is usually sparser on active landslides than on adjacent stable ground; if trees are present, they are usually “jackstrawed” (i.e., leaning), indicating that ground movement has occurred since they became established. Dormant landslide features have typically been modified by weathering, erosion, and vegetative growth and succession. Active landslides are generally more unstable than dormant landslides and may require mitigation measures to avoid mobilization. Excavation, the use of heavy equipment, soil saturation, or the removal of root support can mobilize active landslides. Although dormant landslides are less likely to be mobilized by human activities, portions of dormant landslides (e.g., their steep headwalls and margins) are often unstable.

Several types of landslides and associated landforms can be associated with vegetation management in California and are described below. These landforms have distinct hazard indicators and require special management practices to reduce the hazard.

* Translational and rotational landslides are moderate or slow, relatively deep-seated movements of typically cohesive rock masses. Translational slides consist of downward displacements of material parallel to the ground surface; they commonly occur along bedding planes, faults, and contacts between bedrock and overlying deposits. Rotational slides (or “slumps”) occur along a well-defined curved surface and are likely to occur in incompetent, clayey bedrock material under saturated soil conditions. Most translational and rotational slides feature a nearly vertical scarp near their head or sides. Slide deposits are typically hummocky. The presence of sag ponds or water loving vegetation may indicate the impaired drainage that is characteristic of slide deposits.
* Earth flows consist of the slow movement of saturated soil and debris, often following a slump. They are composed of clay-rich materials that swell when wet, thus reducing intergranular friction and shear strength. They usually occur in areas where low soil permeability restricts groundwater movement. They often feature hummocky, highly erodible surfaces.
* Debris slides refer to the movement of unconsolidated material along a shallow, flat failure plane. They usually occur on slopes exceeding 65 percent where shallow bedrock forms an impervious layer that concentrates water near the surface. Debris slides often occur during intense storms in response to excessive pore water pressure within the saturated surface layer. As with other landslides, the presence of bedding planes aligned parallel to the slope is an indicator of high debris slide hazard.
* Debris slides are characterized by unconsolidated rock, colluvium, and soil that has moved downslope along a relatively shallow translational failure plane (Highland and Bobrowsky 2008). Although areas within these landforms are typically well-vegetated, they usually also feature debris slide scars, incised depressions, areas of active debris sliding, and exposed bedrock.
* Debris flows are often initiated by the discharge of material into a stream channel from debris slides on adjacent hillslopes or by failure of fill materials at stream crossings caused by high flows. Debris flows are commonly caused by debris sliding or the failure of fill materials along stream crossings in the upper part of a drainage during high intensity storms (Highland and Bobrowsky 2008). Post-fire debris flows are well noted in the Transverse and Peninsular Ranges provinces (Oakley et al. 2017).
* Inner gorges are over steepened stream banks extending from the stream channel to the first break in the slope above the channel. The slope generally exceeds 65 percent and is formed by debris sliding and erosion caused primarily by the down cutting of the stream channel and undercutting of landslide toes by stream erosion (CGS 2013).

Landslide susceptibility is the relative likelihood that landsliding will occur. For the purposes of demonstrating landslide susceptibility for the affected area, landsliding can be broken into two categories; shallow-seated and deep-seated landsliding. Shallow-seated landsliding occurs in the regolith – the unconsolidated earth material and soil overlying bedrock. Deep-seated landsliding occurs below the regolith and includes failure into bedrock. Shallow landsliding typically occurs on slopes greater than 65 percent (CGS 2013), and in steep, convergent areas. Deep-seated landsliding is primarily a function of rock strength and slope, but it is also affected by precipitation and earthquake potential (CGS 2013). Shallow-landsliding occurrence is most likely to occur in the mountainous portions of the Coast Ranges, Klamath Mountains, Transverse Ranges, and the Sierra Nevada. Figure 3.7-3 shows the modeled susceptibility for deep-seated landsliding performed by the California Geological Survey (2013). Figure 3.7-3 indicates that the highest susceptibility for deep-seated landsliding is in the Coast Ranges, Klamath Mountains, and Transverse Ranges provinces. The treatable landscape in the Coast Ranges and Transverse Ranges provinces include overlap with areas susceptible for deep-seated landsliding. The majority of the Klamath Mountains treatable area is located in the east of the province where landslide susceptibility is more moderate.

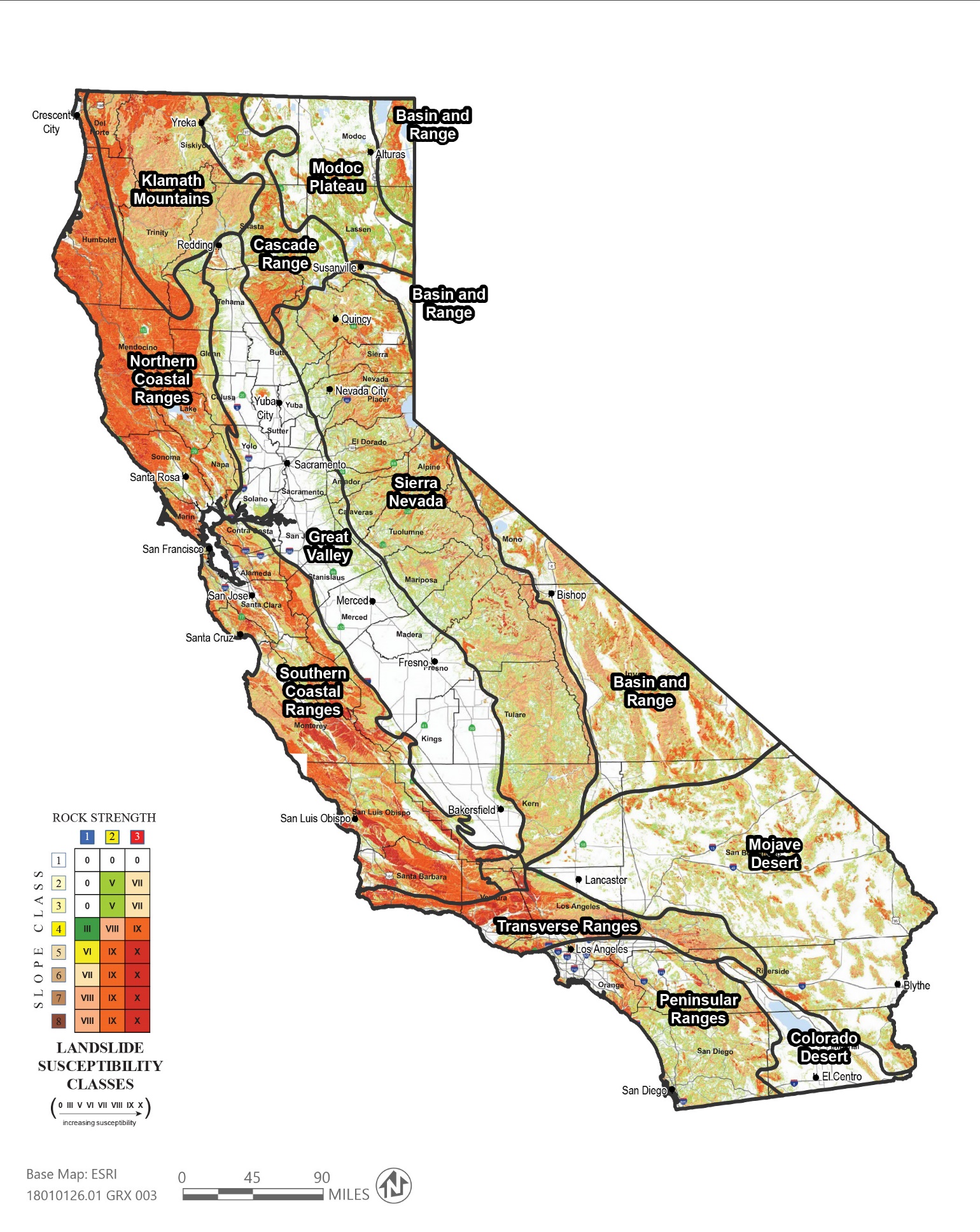
###### Wildfire and Landslide Risk

Moderate to high severity wildfire can greatly increase the likelihood of debris sliding and debris flows (Haas et al 2017). Wildfire can significantly alter the hydrologic response of a watershed to the extent that even modest rainstorms can produce dangerous flash floods and debris flows. The joint probability of a wildland fire event followed by a debris flow is driven by many factors. The debris-flow potential after a fire is a function of the percent of area that burned at a moderate to high severity (Haas et al. 2017). In existing models, the primary variable connecting a wildfire and a subsequent debris flow is the amount of a watershed that burns with moderate to high severity (Haas et al. 2017).

Fires that burn with low severity can maintain soil cover, mineralize important nutrients from plant matter stored on the soil surface, reduce fuel loads leading to possible future high burn severity, and stimulate herbaceous vegetation helping to facilitate nutrient cycling. Moderate to high-severity fires can cause a loss of soil hydrologic function by sealing pores and degrading soil structure; it can cause a loss of soil productivity by processes of erosion, mass-wasting, and nutrient volatization and allow exotic plants to establish which can affect soil productivity.

##### Soil Erosion

Soil erosion is caused by the detachment and entrainment of soil particles through the action of water and wind and can be classified into four general types: rain splash, sheet, rill, and gully erosion. Sheet erosion is the removal of soil of a generally uniform depth across a slope and is caused by non-concentrated runoff. Rill erosion refers to the removal of soil in shallow (i.e., less than approximately 6 inches deep), usually parallel, channels from a slope and is caused by concentrated runoff. Gully erosion consists of removal of soil from deeper channels and is also caused by concentrated runoff. Although usually less conspicuous than rill and gully erosion, sheet erosion tends to result in



Source: Willis et al. 2011

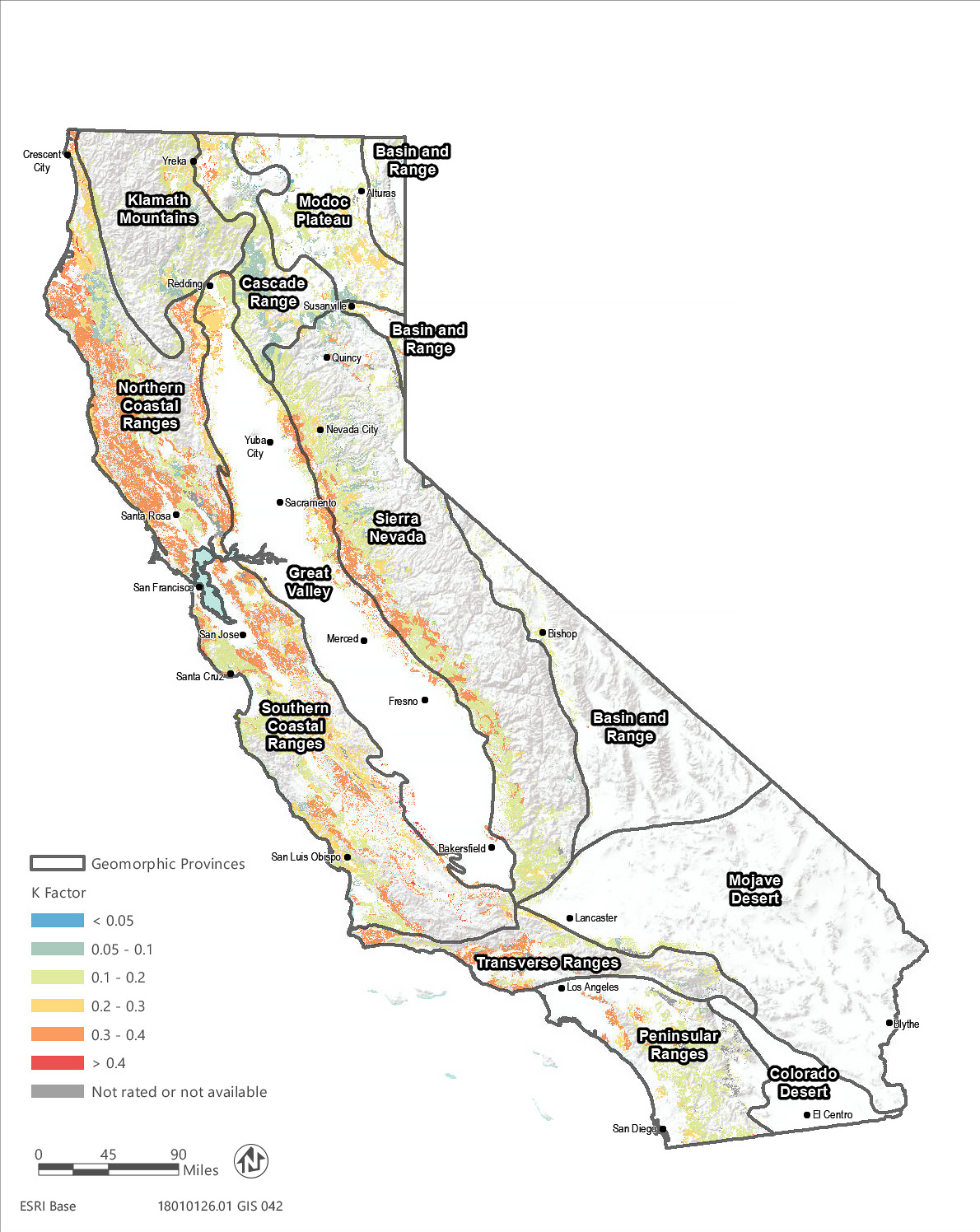
Figure 3.7-3 Landslide Susceptibility

greater soil loss over a wide area. Soils most susceptible to erosion are those high in coarse silt- and fine sand-sized particles (Balasubramanian 2017), particularly when organic matter content is low and soil structure is weak or nonexistent. The likelihood of erosion is greater when the vegetative cover is removed or reduced, the soil is otherwise disturbed, or when both of these conditions exist. Soil erosion by water is more aggressive on steep slopes than on shallow slopes (e.g., 10 percent gradient or less), because at lower slope gradients surface runoff cannot reach peak velocities necessary to erode the soil. In general, areas with less vegetative cover are more prone to soil erosion than heavily vegetated areas, because surface cover and additional soil structure from plant roots can reduce soil erosion potential. Soil erosion can also be caused by wind in areas with a combination of high winds, removed or disturbed vegetation, fine sandy or silty textures, and low organic matter content. The erosion rate of a particular soil in the absence of human activities is referred to as the natural (background) or geologic erosion rate. Soil erosion in excess of the natural erosion rate is called accelerated soil erosion and is usually caused by poorly implemented human activities such as cultivation, grazing, timber harvesting, ~~poor~~ road construction ~~practices~~, grading, and other land-disturbing activities. Additionally, surface erosion from high severity wildfire can increase runoff and erosion rates by two or more orders of magnitude relative to unburned conditions (Robichaud et al. 2010).

Erodibility by water is calculated using the K factor, an index which quantifies the relative susceptibility of the soil to sheet and rill erosion. Soil properties affecting the K factor include texture, organic matter content, structure, and saturated hydraulic conductivity, and values range from 0.02 for the least erodible soils to 0.64 for the most erodible (NRCS 2019b). In California the Transverse Ranges, Peninsular Ranges, Sierra Nevada, Coastal Ranges, Klamath Mountains, and Cascade Range geomorphic provinces are the most susceptible to erosion (Figure 3.7-4). The treatable landscape within the Transverse Ranges overlaps with the areas most susceptible to erosion throughout the province, with the exception of the area with very high erodibility risk in the north central part of the province which is not in the treatable area. In the Peninsular Ranges, the high erodibility risk areas in the central portion of the province overlaps with the treatable area. The high erodibility risk of the western slope of the Sierra Nevada overlaps the treatable area. In the northern portion of the Coastal Ranges, the high erodibility risk area overlaps with the treatable landscape. In the southern portion of the Coastal Ranges, the areas of highest erodibility risk are not in the treatable landscape, but there are some areas of overlap. The Klamath Mountains have high erodibility risk throughout the province with slightly higher risk of erosion in the east which includes the treatable landscape. The Cascade Range has a high erodibility risk in the central and southern portions of the province which include the treatable landscape.

###### Wildfire and Erosion Risk

The Forest and Range 2003 Assessment (FRAP 2003) used a modified form of the universal soil loss equation to predict soil loss as a result of wildfire throughout California. The inputs into this model include steepness, soil friability, expected fire intensity, and expected storm intensity. Most mountainous areas of the State are likely to result in High or Very High levels of post-wildfire erosion (FRAP 2003). The South Coast chaparral region has the highest risk of the erosion Statewide along with the highest expected frequencies of wildfire (FRAP 2003).



Source: Data downloaded from NRCS in 2019; adapted by Ascent Environmental in 2019

Figure 3.7-4 Erosion Susceptibility within the Treatment Landscape

### Regulatory Setting

#### Federal

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

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

##### Earthquake Hazards Reduction Act (Public Law 95-124, 42 U.S.C. 7701 et. Seq)

The purpose of this Act to reduce the risks of life and property from future earthquakes in the United States through the establishment and maintenance of an effective earthquake hazards reduction program. The objectives of the program include: (1) the education of the public; (2) the development of technologically and economically feasible design and construction methods and procedures; (3) the implementation of a system for predicting damaging earthquakes and for identifying seismic hazards; (4) the development of model building codes; (5) the development of methods of mitigating the risks from earthquakes; (6) increase the use of existing scientific and engineering knowledge to mitigate earthquake hazards; and (7) the development of ways to assure the availability of affordable earthquake insurance.

##### Clean Water Act (33 USC Section 1251 Et Seq.)

The Federal Water Pollution Control Act of 1948 was the first major U.S. law to address water pollution. Growing public awareness and concern for controlling water pollution led to sweeping amendments in 1972. As amended in 1972, the law became commonly known as the Clean Water Act (CWA). The CWA serves as the primary federal law protecting the quality of the nation’s surface waters, including wetlands. The CWA provides standard regulations for the discharge of pollutants to the waters of the United States (U.S.) in order to maintain their chemical, physical, and biological integrity and protect their beneficial uses. In addition, the CWA provides the statutory basis for the National Pollutant Discharge Elimination System (NPDES). The CWA requires states to adopt water quality standards that must be approved by the U.S. Environmental Protection Agency (EPA) and requires NPDES permits for the discharge of pollutants in U.S. waters. In addition, the CWA gives authority to the EPA to (1) implement pollution control programs, including setting waste water standards and effluent limits on an industry-wide basis; and (2) authorize the NPDES Permit Program permitting, administration, and enforcement to state governments with oversight by the EPA.

##### Federal Antidegradation Policy (Code of Federal Regulations – Title 40: Protection of Environment 40 CFR 131.12)

The Federal Antidegradation Policy was issued in 1968 by the U.S. Department of the Interior to (1) ensure that activities will not lower the water quality of existing use, and (2) restore and maintain “high quality water.” The federal policy maintains that states shall adopt a statewide antidegradation policy that includes the following conditions:

* Existing instream water uses and a level of water quality necessary to maintain those uses shall be maintained and protected.
* Water quality will be maintained and protected in waters that exceed water quality levels necessary for supporting fish, wildlife, and recreational activities, and water quality, unless the State deems that water quality levels can be lowered to accommodate important economic or social development. In these cases, water quality levels can only be lowered to levels that support all existing uses.
* Where high quality waters constitute an outstanding National resource, such as waters of National and State parks and wildlife refuges and waters of exceptional recreational or ecological significance, that water quality shall be maintained and protected.

#### State

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

This act provides policies and criteria to assist cities, counties, and state agencies in the exercise of their responsibilities to prohibit the location of developments and structures for human occupancy across the trace of active faults. The act also requires site-specific studies by licensed professionals for some types of proposed construction within delineated earthquake fault zones.

##### Porter-Cologne Water Quality Act (Cal. Water Code Div. 7)

The Porter-Cologne Water Quality Act is a key element of California water quality control legislation. Under the act, the State Water Resources Control Board (SWRCB) is given authority over state water rights and water quality policy and it established the State’s nine regional water quality control boards (RWQCBs) to regulate and oversee regional and local water quality issues. The RWQCB is also responsible for developing and updating Basin Plans targeted toward (1) protecting waters designated with beneficial uses, (2) establishing water quality objectives for surface water and groundwater, and (3) determining actions necessary to maintain water quality standards and control point- and nonpoint-sources of pollution into the State’s waters. Under the Act, proposed waste dischargers are required to file Reports of Waste Discharge to the RWQCB and the SWRCB and RWQCB are granted jurisdiction over the issuance and enforcement of Waste Discharge Requirements, NPDES permits, and Section 401 water quality certifications.

##### California State Antidegradation Policy (SWRCB Resolution No. 68-16, “Policy with Respect to Maintaining higher quality waters in California”)

In 1968, the State of California adopted an antidegradation policy in response to directives under the Federal Antidegradation Policy. The antidegradation policy applies to high quality waters of the State, including surface waters and groundwater, and all existing and potential uses. The policy requires that high quality waters be maintained to the maximum extent possible and any proposed activities that can adversely affect high quality surface water and groundwater must (1) be consistent with the maximum benefit to the people of the State, (2) not unreasonably affect present and anticipated beneficial use of the water, and (3) not result in water quality less than that prescribed in water quality plans and policies.

##### California Coastal Act

The California Coastal Commission’s coastal zone generally extends 1,000 yards inland from the mean high tide line and is specifically designated on maps held by the Legislature. In significant coastal estuarine habitat and recreational areas, it extends inland to the first major ridgeline or five miles from the mean high tide line, whichever is less. In developed urban areas, the boundary is generally less than 1,000 yards.

The Coastal Commission’s coastal program uses a variety of planning, permitting, regulatory, and non-regulatory mechanisms to manage ~~its~~ coastal resources. The Coastal Commission implements a well-established permitting and planning program, including ~~issuing~~ issuance of CDPs for proposed development, review~~ing~~ and approval of local governments’ Local Coastal Programs, ~~reviewing~~ consideration of appeals of certain locally permitted CDPs, and, under the Coastal Zone Management Act, federal consistency reviews of federal agency, federally-permitted, and federally-funded (to state and local government) activities.

##### Z’berg-Nejedly Forest Practice Act

Although the proposed CalVTP excludes timber removal for commercial purposes, the Z’berg -Nejedly Forest Practice Act (Forest Practice Act) may be pertinent as it relates to identifying operating methods and procedures that seek to protect fish, wildlife, forests, and streams within timber harvesting areas where qualifying CalVTP treatments may also be implemented. The Forest Practice Act is intended to achieve “maximum sustained production of high-quality timber products…while giving consideration to values relating to recreation, watershed, wildlife, range and forage, fisheries, regional economic vitality, employment and aesthetic enjoyment” (PRC Section 4513[b]). The regulations created by the Forest Practice Act define factors such as the: size and location of harvest areas, include measures to prevent unreasonable damage to residual trees, and address the protection of riparian areas, water courses and lakes, wildlife, and habitat areas.

#### Local

When state agencies, including CAL FIRE, are conducting governmental activities under the authority of state law or the State Constitution, in this case, treatments implemented under the CalVTP, they are not subject to local government plans, policies, and ordinances (unless a constitutional provision or statute directs otherwise). Nonetheless, CAL FIRE voluntarily seeks to operate consistently with local governance to the maximum extent feasible. Given its statewide extent and the possible number of local and regional responsible agencies, this PEIR does not identify potentially applicable local government plans, policies, and ordinances. Types of local regulations relevant to geology, soils, paleontology, and mineral resources include general plans, city and county codes, and other local ordinances. This PEIR assumes that any vegetation treatments proposed by local or regional agencies under the CalVTP would be consistent with local plans, policies, and ordinances to the extent the project is subject to them, as required by SPR AD-3.

### Impact Analysis and Mitigation Measures

#### Analysis Methodology

With regard to geology and soils, the impact analysis focuses on the changes to the existing or baseline geologic and soil conditions in the context of the thresholds of significance listed below. Impacts are assessed by evaluating potential impacts from unstable geology and soils, earthquakes, and landslides associated with the implementation of the CalVTP.

This analysis considers impacts of vegetation treatment under the proposed program on geologic and soil resources. Significance determinations assume that project proponents implementing qualifying treatments under the CalVTP would comply with relevant federal, state, and local ordinances and regulations to the extent the project is subject to them. Significance determinations also account for the influence of relevant SPRs, which are incorporated into treatment design.

* **SPR AD-3 Consistency with Local Plans, Policies, and Ordinances**: The project proponent will design and implement the treatment in a manner that is consistent with applicable local plans (e.g., general plans, Community Wildfire Protection Plans, CAL FIRE Unit Fire Plans), policies, and ordinances to the extent the project is subject to them. This SPR applies to all treatment activities and treatment types, including treatment maintenance.
* **SPR AQ-3 Create Burn Plan**: The project proponent will create a burn plan using the CAL FIRE burn plan template for all prescribed burns. The burn plan will include a fire behavior model output of First Order Fire Effects Model and BEHAVE or other fire behavior modeling simulation and that is performed by a qualified fire behavior technical specialist that predicts fire behavior, calculates consumption of fuels, tree mortality, predicted emissions, greenhouse gas emissions, and soil heating. The project proponent will minimize soil burn severity from broadcast burning to reduce the potential for runoff and soil erosion. The burn plan will be created with input from a qualified technician or certified State burn boss. This SPR applies only to prescribed burning treatment activities and all treatment types, including treatment maintenance.
* **SPR AQ-4 Minimize Dust**: To minimize dust during treatment activities, the project proponent will implement the following measures:
* Limit the speed of vehicles and equipment traveling on unpaved areas to 15 miles per hour to reduce fugitive dust emissions, in accordance with the California Air Resources Board (CARB) Fugitive Dust protocol.
* If road use creates excessive dust, the project proponent will wet appurtenant, unpaved, dirt roads using water trucks or treat roads with a non-toxic chemical dust suppressant (e.g., emulsion polymers, organic material) during dry, dusty conditions. Any dust suppressant product used will be environmentally benign (i.e., non-toxic to plants and will not negatively impact water quality) and its use will not be prohibited by CARB, EPA, or the State Water Resources Control Board (SWRCB). The project proponent will not over-water exposed areas such that the water results in runoff. The type of dust suppression method will be selected by the project proponent based on soil, traffic, site-specific conditions, and air quality regulations.
* Remove visible dust, silt, or mud tracked-out on to public paved roadways where sufficient water supplies and access to water is available. The project proponent will remove dust, silt, and mud from vehicles at the conclusion of each workday, or at a minimum of every 24 hours for continuous treatment activities, in accordance with Vehicle Code Section 23113.
* Suspend ground-disturbing treatment activities, including land clearing and bulldozer lines, when there is visible dust transport (particulate pollution) outside the treatment boundary, if the particulate emissions may “cause injury, detriment, nuisance, or annoyance to any considerable number of persons or to the public, or that endanger the comfort, repose, health, or safety of any of those persons or the public, or that cause, or have a natural tendency to cause, injury or damage to business or property,” per Health and Safety Code Section 41700.

This SPR applies to all treatment activities and treatment types, including treatment maintenance.

* **SPR GEO-1 Suspend Disturbance during Heavy Precipitation:** The project proponent will suspend mechanical, prescribed herbivory, and herbicide treatments if the National Weather Service forecast is a “chance” (30 percent or more) of rain within the next 24 hours. Activities that cause mechanical soil disturbance may resume when precipitation stops and soils are no longer saturated (i.e., when soil and/or surface material pore spaces are filled with water to such an extent that runoff is likely to occur). Indicators of saturated soil conditions may include, but are not limited to: (1) areas of ponded water, (2) pumping of fines from the soil or road surfacing, (3) loss of bearing strength resulting in the deflection of soil or road surfaces under a load, such as the creation of wheel ruts, (4) spinning or churning of wheels or tracks that produces a wet slurry, or (5) inadequate traction without blading wet soil or surfacing materials. This SPR applies only to mechanical, prescribed herbivory, and herbicide treatment activities and all treatment types, including treatment maintenance.
* **SPR GEO-2 Limit High Ground Pressure Vehicles:** The project proponent will limit heavy equipment that could cause soil disturbance or compaction to be driven through treatment areas when soils are wet and saturated to avoid compaction and/or damage to soil structure. Saturated soil means that soil and/or surface material pore spaces are filled with water to such an extent that runoff is likely to occur. If use of heavy equipment is required in saturated areas, other measures such as operating on organic debris, using low ground pressure vehicles, or operating on frozen soils/snow covered soils will be implemented to minimize soil compaction. Existing compacted road surfaces are exempted as they are already compacted from use. This SPR applies only to mechanical treatment activities and all treatment types, including treatment maintenance.
* **SPR GEO-3 Stabilize Disturbed Soil Areas:** The project proponent will stabilize soil disturbed during mechanical, ~~and~~ prescribed herbivory treatments, and prescribed burns that result in exposure of bare soil over 50 percent or more of the treatment area with mulch or equivalent immediately after treatment activities, to the maximum extent practicable, to minimize the potential for substantial sediment discharge. If mechanical,  ~~or~~ prescribed herbivory, or prescribed burn treatment activities could result in substantial sediment discharge from soil disturbed by machinery, ~~or~~ animal hooves, or being bare, organic material from mastication or mulch will be incorporated onto at least 75 percent of the disturbed soil surface where the soil erosion hazard is moderate or high, and 50 percent of the disturbed soil surface where soil erosion hazard is low to help prevent erosion. Where slash mulch is used, it will be packed into the ground surface with heavy equipment so that it is sufficiently in contact with the soil surface. This SPR only applies to mechanical, ~~and~~ prescribed herbivory, and prescribed burns that result in exposure of bare soil over 50 percent of the project area treatment activities and all treatment types, including treatment maintenance.
* **SPR GEO-4 Erosion Monitoring:** The project proponentwill inspect treatment areas for the proper implementation of erosion control SPRs and mitigations prior to the rainy season. If erosion control measures are not properly implemented, they will be remediated prior to the first rainfall event per SPR GEO-3 and GEO-8. Additionally, the project proponent will inspect for evidence of erosion after the first large storm or rainfall event (i.e., ≥ 1.5 inches in 24 hours) as soon as is feasible after the event. Any area of erosion that will result in substantial sediment discharge will be remediated within 48 hours per the methods stated in SPRs GEO-3 and GEO-8. This SPR applies only to mechanical, prescribed herbivory, and prescribed burning treatment activities and all treatment types, including treatment maintenance.
* **SPR GEO-5 Drain Stormwater via Water Breaks:** The project proponent will drain compacted and/or bare linear treatment areas capable of generating storm runoff via water breaks using the spacing and erosion control guidelines contained in Sections 914.6, 934.6, and 954.6(c) of the California Forest Practice Rules (February 2019 version). Where waterbreaks cannot effectively disperse surface runoff, including where waterbreaks cause surface run-off to be concentrated on downslopes, other erosion controls will be installed as needed to maintain site productivity by minimizing soil loss. ~~comply with 14 CCR 914 [934, 954].~~ This SPR applies only to mechanical, manual, and prescribed burn treatment activities and all treatment types, including treatment maintenance.
* **SPR GEO-6 Minimize Burn Pile Size:** The project proponent will not create burn piles that exceed 20 feet in length, width, or diameter, except when on landings, road surfaces, or on contour to minimize the spatial extent of soil damage. In addition, burn piles will not occupy more than 15 percent of the total treatment area (Busse et al. 2014). The project proponent will not locate burn piles in a Watercourse and Lake Protection Zone as defined in ~~14 CCR Section 916.5 of the California Forest Practice Rules~~SPR HYD-4. This SPR applies to mechanical, manual, and prescribed burning treatment activities and all treatment types, including treatment maintenance.
* **SPR GEO-7 Minimize Erosion:** To minimize erosion, the project proponent will:

1. Prohibit use of heavy equipment where any of the following conditions are present:

(i) Slopes steeper than 65 percent.

(ii) Slopes steeper than 50 percent where the erosion hazard rating is high or extreme.

(iii) Slopes steeper than 50 percent that lead without flattening to sufficiently dissipate water flow and trap sediment before it reaches a watercourse or lake.

1. On slopes between 50 percent and 65 percent where the erosion hazard rating is moderate, and all slope percentages are for average slope steepness based on sample areas that are 20 acres, or less, heavy equipment will be limited to:

(i) Existing tractor roads that do not require reconstruction, or

(ii) New tractor roads flagged by the project proponent prior to the treatment activity.

1. Prescribed herbivory treatments will not be used in areas with over 50 percent slope.

This SPR applies to all treatment activities and all treatment types, including treatment maintenance.

* **SPR GEO-8 Steep Slopes**: The project proponent will require a Registered Professional Forester (RPF) or licensed geologist to evaluate treatment areas with slopes greater than 50 percent for unstable areas (areas with potential for landslide) and unstable soils (soil with moderate to high erosion hazard). If unstable areas or soils are identified within the treatment area, are unavoidable, and will be potentially directly or indirectly affected by the treatment, a licensed geologist (P.G. or C.E.G.) will determine the potential for landslide, erosion, of other issue related to unstable soils and identity measures (e.g., those in SPR GEO-7) that will be implemented by the project proponent such that substantial erosion or loss of topsoil would not occur. This SPR applies only to mechanical treatment activities and WUI fuel reduction, non-shaded fuel breaks, and ecological restoration treatment types, including treatment maintenance.
* **SPR HYD-3 Water Quality Protections for Prescribed Herbivory:** The project proponent will include the following water quality protections for all prescribed herbivory treatments:
* Environmentally sensitive areas such as waterbodies, wetlands, or riparian areas will be identified in the treatment prescription and excluded from prescribed herbivory project areas using temporary fencing or active herding. A buffer of approximately 50 feet will be maintained between sensitive and actively grazed areas.
* Water will be provided for grazing animals in the form of an on-site stock pond or a portable water source located outside of environmentally sensitive areas.
* Treatment prescriptions will be designed to protect soil stability. Grazing animals will be herded out of an area if accelerated soil erosion is observed.

This SPR applies to prescribed herbivory treatment activities and all treatment types, including treatment maintenance.

* **SPR HYD-4 Identify and Protect Watercourse and Lake Protection Zones:** The project proponent will establish Watercourse and Lake Protection Zones (WLPZs) on either side of watercourses as defined in the table below, which is based on~~in~~ 14 CCR Section 916 .5 of the California Forest Practice Rules (February 2019 version)~~on either side of watercourses~~. WLPZ’s are classified based on the uses of the stream and the presence of aquatic life. Wider WLPZs are required for steep slopes.

Procedures for Determining Watercourse and Lake Protection Zone (WLPZ) widths

| Water Class | Class I | Class II | Class III | Class IV |
| --- | --- | --- | --- | --- |
| Water Class Characteristics or Key Indicator Beneficial Use | 1) Domestic supplies, including springs, on site and/or within 100 feet downstream of the operations area and/or  2) Fish always or seasonally present onsite, includes habitat to sustain fish migration and spawning. | 1) Fish always or seasonally present offsite within 1000 feet downstream and/or  2) Aquatic habitat for nonfish aquatic species.  3) Excludes Class III waters that are tributary to Class I waters. | No aquatic life present, watercourse showing evidence of being capable of sediment transport to Class I and II waters under normal high-water flow conditions after completion of timber operations. | Man-made watercourses, usually downstream, established domestic, agricultural, hydroelectric supply or other beneficial use. |
| WLPZ Width (ft) – Distance from top of bank to the edge of the protection zone | | | | |
| < 30 % Slope | 75 | 50 | Sufficient to prevent the degradation of downstream beneficial uses of water. Determined on a site-specific basis. | |
| 30-50 % Slope | 100 | 75 |
| >50 % Slope | 150 | 100 |

Source: 14 CCR Section 916.5 [936.5, 956.5] (February 2019 version)

The following WLPZ protections will be applied for all treatments:

* Treatment activities with WLPZs will ~~meet the overstory and understory vegetation retention guidelines and ground disturbance limitations described in 14 CCR Section 916.4 [936.4, 956.4] Subsection (b) and Section 916.5, including retention of at least 75 percent surface cover and undisturbed area.~~ retain at least 75 percent surface cover and undisturbed area to act as a filter strip for raindrop energy dissipation and for wildlife habitat. If this percentage is reduced, a qualified RPF will provide the project proponent with a site- and/or treatment activity-specific explanation for the percent surface cover reduction, which will be included in the PSA. After completion of the PSA and prior to or during treatment implementation, if there is any deviation (e.g., further reduction) from the reduced percent as explained in the PSA, this will be documented in the post-project implementation report (referred to by CAL FIRE as a Completion Report). This requirement is based on 14 CCR Section 916.4 [936.4, 956.4] Subsection (b)(6) (February 2019 version) and 14 CCR Section 916.5 (February 2019 version).
* Equipment, including tractors and vehicles, must not be driven in wet areas or WLPZs, except over existing roads or watercourse crossings where vehicle tires or tracks remain dry.
* Equipment used in vegetation removal operations will not be serviced in WLPZs, within wet meadows or other wet areas, or in locations that would allow grease, oil, or fuel to pass into lakes, watercourses, or wet areas.
* WLPZs will be kept free of slash, debris, and other material that harm the beneficial uses of water. Accidental deposits will be removed immediately.
* Burn piles will be located outside of WLPZs.
* No fire ignition (nor use of associated accelerants) will occur within WLPZs however low intensity backing fires may be allowed to enter or spread into WLPZs.
* ~~Large areas of bare soil within WLPZs that are exposed by treatment activities will be stabilized with mulching, rip-rap, grass seeding, or soil stabilizers prior to the beginning of the rainy season, as described in 14 CCR 916.7.~~Within Class I and Class II WLPZs, locations where project operations expose a continuous area of mineral soil 800 square feet or larger shall be treated for reduction of soil loss. Treatment shall occur prior to October 15th and disturbances that are created after October 15th shall be treated within 10 days. Stabilization measures shall be selected that will prevent significant movement of soil into water bodies and may include but are not limited to mulching, rip-rap, grass seeding, or chemical soil stabilizers.

Where mineral soil has been exposed by project operations on approaches to watercourse crossings of Class I, II, or III within a WLPZ, the disturbed area shall be stabilized to the extent necessary to prevent the discharge of soil into watercourses or lakes in amounts that would adversely affect the quality and beneficial uses of the watercourse.

Where necessary to protect beneficial uses of water from project operations, protection measures such as seeding, mulching, or replanting shall be used to retain and improve the natural ability of the ground cover within the WLPZ to filter sediment, minimize soil erosion, and stabilize banks of watercourses and lakes.

* Equipment limitation zones (ELZs) will be designated adjacent to Class III and Class IV watercourses with minimum widths of 25 feet where side-slope is less than 30 percent and 50 feet where side-slope is 30 percent or greater. An RPF will describe the limitations of heavy equipment within the ELZ and, where appropriate, will include additional measures to protect the beneficial uses of water.

This SPR applies to all treatment activities and treatment types, including treatment maintenance.

#### Thresholds of Significance

Thresholds of significance are based on Appendix G of the State CEQA Guidelines. A treatment implemented under the proposed CalVTP would result in a significant impact on geology, soils, paleontology, and mineral resources if it would:

* Directly or indirectly cause potential substantial adverse effects, including the risk of loss, injury, or death involving:
* 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 California Geological Survey Special Publication 42.)
* Strong seismic ground shaking
* Seismic-related ground failure, including liquefaction
* 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, as defined in Table 18-1-B of the Uniform Building Code (1994, as updated), creating substantial direct or indirect risks to life or property
* Have soils incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems where sewers are not available for the disposal of waste water
* Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature
* Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state
* Result in the loss of availability of a locally important mineral resource recovery site delineated on a local general plan, specific plan, or other land use plan

#### Issues Not Evaluated Further

Because the CalVTP does not propose any excavation or development, the following issues are not evaluated further:

* **Seismic or secondary seismic hazards.** The CalVTP would not directly or indirectly cause substantial adverse effects involving rupture of a known earthquake fault or strong seismic ground shaking; therefore, this issue is not evaluated further. The CalVTP would not include construction of structures that could be affected by seismic or secondary seismic hazards.
* **Lateral spreading, subsidence, liquefaction, or collapse due to unstable or expansive soil.** The CalVTP does not include the construction of any structures such as earthen embankments or dams that would be adversely affected by unstable or expansive soils that would jeopardize structural integrity; therefore, there would be no risk to life and property from operation on unstable or expansive soils. This issue is not discussed further. The potential for landslides and erosion are evaluated in Impacts GEO-1 and GEO-2.
* **Soils incapable of supporting septic tanks or alternative waste water disposal.** The CalVTP does not include the construction of septic tanks or wastewater treatment systems therefore this issue is not discussed further.
* **Destruction of unique paleontological resource or site or unique geologic feature.** The fossil yielding potential of a particular area is highly dependent on the geologic age and origin of the underlying rocks, which vary in distribution and surface exposure throughout the state. All sedimentary rocks, some volcanic rocks, and some metamorphic rocks have potential for the presence of scientifically significant, nonrenewable paleontological resources. Because treatment activities under the proposed CalVTP would not include excavation beyond the potential disturbance of the top inches of soil during some manual treatments (e.g., mastication), there is no potential to disturb paleontological or unique geologic features. Therefore, implementation of the CalVTP would not directly or indirectly destroy a unique paleontological resource or site or unique geologic feature. This issue is not evaluated further.
* **Loss of availability of a known mineral resource or locally important mineral resource recovery site.** Treatment activities under the CalVTP would not include mineral extraction. Treatments would be short-term and would not obstruct access to any mineral resources so it will have no impact on the availability of mineral resources or on the loss of availability of a known mineral resource or locally important mineral resource recovery site.

#### Impact Analysis

Impact GEO-1: Result in Substantial Erosion or Loss of Topsoil

Treatment activities implemented under the proposed CalVTP may involve the disturbance of soils as well as the reduction in vegetative cover, which has the potential to substantially increase rates of erosion and loss of topsoil. Mechanical treatments using heavy machinery are the most likely to cause soil disturbance which could lead to substantial erosion or loss of topsoil especially in areas of steep slopes. In general, it is highly likely that mechanical treatments (relative to other treatment activities) would be utilized for all treatment types in tree fuel types as well as for WUI fuel reduction treatments in shrub fuel types. Additionally, prescribed burning can increase risk of water repellency (Robichaud et al. 2010) and breakdown of soil structure, which can lead to significant increases in erosion. There is a high likelihood that prescribed burning would be utilized most for ecological restoration treatments in grass fuel types, a moderate likelihood it would be utilized to implement fuel break and ecological restoration treatments in tree fuel types, and a moderate likelihood it would be utilized for fuel break treatments in shrub fuel types. The CalVTP would reduce the amount of vegetation in all treated areas, which has the potential to expose soil to wind and water erosion. Implementation of SPRs GEO-1 through GEO-8 will avoid and minimize the risk of substantial erosion and loss of topsoil. This impact would be **less than significant**.

The effects of treatment activities on erosion and sediment yields depend on techniques used, site characteristics, storm events following treatments, and skills of the equipment operators (Robichaud et al 2010). Implementation of treatments under the CalVTP has the potential to increase rates of soil erosion and loss of topsoil. Different vegetation treatment activities result in different potential impacts to geologic and soil resources. The impacts from prescribed burning, mechanical, manual, prescribed herbivory, and herbicides are described in detail in Tables 3.7-3 through 3.7-4. Risk of erosion is also analyzed in Impacts HYD-1, HYD-2, and HYD-3 in Section 3.11.

Table 3.7-3 Potential Impacts to Geologic and Soil Resources from Prescribed Burning

| Activity | Impact Type | Potential Impacts to Geologic and Soil Resources |
| --- | --- | --- |
| Prescribed Burning |  |  |
|  | Soil disturbance | Pile burning can completely consume the duff and organic layer under high soil burn severity (USDA 2005). Removing the organic layer can expose mineral soil to rain splash and overland flow. Combustion of organic matter within the mineral soil can cause soil disaggregation, further increasing soil erodibility (Robichaud et al. 2010). Heating from the burn pile may create a water repellent layer in the soil. |
| Pile Burn | Increased runoff | Water repellency, lack of cover, and the increased likelihood of soil sealing can lead to overland flow generation in the areas where piles were burned (Larsen et al. 2009, Robichaud et al. 2010). |
|  | Increased fluvial erosion | Increased overland flow and exposure of mineral soil can lead to rain splash, sheetwash, and rill erosion within the footprint of the burn pile (Reid 2010, Robichaud et al. 2010). |
|  | Soil disturbance | Broadcast burning can remove litter and surface fuels under low soil burn severity or can completely consume the duff and organic layer under high burn severity. Removing the organic cover layer can expose mineral soil to rain splash and overland flow. Combustion of organic matter within the mineral soil can cause soil disaggregation, further increasing soil erodibility. Increased water repellency and the breakdown of soil structure will reduce the infiltration rate, and thereby increase erosion potential (Robichaud et al. 2010). |
| Broadcast Burn | Increased runoff | If soil burn severity is high, post-fire reduction of infiltration capacity and the increased likelihood of soil sealing will lead to overland flow generation. Burning large areas can result in the excess surface flow being routed to convergent areas and low order streams (Robichaud et al. 2010). |
|  | Increased fluvial erosion | If burn severity is high, increased overland flow and exposure of mineral soil can lead to rain splash, sheetwash, and rill erosion (Robichaud et al., 2010). Runoff concentration in convergent areas may lead to gully erosion, and excess runoff routed into low order streams may potentially lead to bank erosion (Reid 2010). Fire may burn large woody debris in channel, resulting in the release of stored sediment (Reid 2010). |
|  | Increased mass wasting | Decreased evapotranspiration will increase soil moisture, potentially increase pore pressure, thereby reducing the resistance to landsliding. Increased surface runoff may initiate debris flows in steep convergent areas. Stream adjacent hillslopes may be undercut by increased flow, thereby triggering shallow debris slides (Reid 2010). |

Table 3.7-4 Potential Impacts to Geology and Soil Resources from Mechanical, Manual, Herbivory, and Herbicides

| Activity | Impact Type | Potential Impacts to Geologic and Soil Resources |
| --- | --- | --- |
| Mechanical, Manual, Prescribed Herbivory, and Herbicides |  |  |
|  | Soil disturbance | Use of mechanical equipment can compact soils or cause rutting (Page-Dumroese et al. 2010), especially during saturated soil conditions. Mechanical equipment can decrease soil cover and the churning forces of tread or tire traffic can break down soil structure and increase the erodibility of the soil. Heavy equipment on steep slopes can cause extensive soil disturbance. Potential impacts will be greatest in shrub and grass-dominated areas due to complete removal of the fuels/soil cover. |
| Mechanical | Increased runoff | Compacted soil will reduce infiltration capacity and generate overland flow (Robichaud et al. 2010). Bare soils are prone to producing overland flow through soil sealing. Equipment tracks can concentrate runoff. |
|  | Increased fluvial erosion | Increased surface runoff and the availability of easily transportable soil increases the likelihood of rain splash, sheetwash, rill, and gully erosion (Reid 2010, Robichaud et al. 2010). |
|  | Increased mass wasting | Compaction from trails and soil disturbance may generate overland flow that is routed to an unstable area. Removal of vegetation may result in increased soil moisture which can reduce the resisting forces to landsliding (Reid 2010). |
| Manual/Hand | Soil Disturbance | Soil disturbance from hand treatments is considered negligible (Robichaud et al. 2010). |
|  | Soil disturbance | Mechanical force from the animal’s hoof can compact soil on gentler slopes, and shear and move soil in the downslope direction. When soils have high moisture content, hoof deformation can be even deeper. Animals can form trails or paths through repeated trampling and can induce bank erosion through hoof sheer. Combination of grazing and trampling can reduce soil cover (Trimble and Mendel 1995). |
| Prescribed herbivory | Increased runoff | Compaction through trampling lowers the infiltration rate and increases the likelihood of overland flow (Salls et al. 2018). Trails and/or paths created by the animals can concentrate runoff and alter drainage patterns (Trimble and Mendel 1995). |
|  | Increased fluvial erosion | Increased runoff and bare erodible soil increase the likelihood of rain splash, sheetwash, and rill erosion. Animal trails/paths can concentrate runoff and initiate gullying (Trimble and Mendel 1995, Stednick 2010). |
| Herbicides | See Water Quality Section | See Water Quality Section 3.11 |

One causal mechanism for erosion is the risk of soil disturbance during mechanical fuel treatment activities. This is due to compaction caused by mechanical equipment, loss of soil cover, and the churning and breakdown of soil structure by mechanical equipment (Page-Dumroese et al. 2010). To address this risk, SPR GEO-1 which requires suspension of mechanical soil disturbance during precipitation, SPR GEO-2 which limits high ground pressure vehicles, SPR GEO-3 which requires stabilization of mechanically disturbed soil areas, SPR GEO-4 which requires inspection prior to the rainy season and immediately following the first large rainfall event, and SPR AQ-4 which requires wetting of unpaved, dirt roads to control dust would be implemented. Soil disturbance and erosion from heavy equipment is typically greater on steeper slopes (Grigal 2000) which would be addressed by SPR GEO-7 which minimizes erosion from use of heavy equipment on slopes and SPR GEO-8 which requires evaluation of treatment areas with slopes greater than 50 percent for unstable areas. Herbivory can also lead to erosion of stream banks and can create linear erosion features on animal trails (Trimble and Mendel 1995). However, herds would be moved often, and reducing the likelihood of causing substantial erosion. In addition, SPRs HYD-3 HYD-4 will require that environmentally sensitive areas such as waterbodies, wetlands, or riparian areas be identified and excluded from prescribed herbivory project areas, grazing animals will be herded out of an area if accelerated soil erosion is observed, and treatments would avoid impacts to WLPZs. Another causal mechanism for impacts is the risk of soil disturbance during prescribed burning activities (i.e., pile burning and broadcast burning). Depending on the severity of the fire, prescribed burning could cause loss of soil cover (Larsen et al. 2009), increased risk of water repellency (Robichaud et al. 2010), and breakdown of soil structure (Robichaud et al. 2010). High severity wildfires increase runoff and erosion rates by two or more orders of magnitude, while low and moderate severity burns have much smaller effects on runoff and sediment yields (Robichaud et al. 2010). Fire induced vegetation and litter removal and post-fire soil exposure significantly reduce surface roughness and overland flow resistance, increasing the risk and erodibility of overland flow (Stoof 2011). SPR GEO-6 addresses this impact by minimizing burn pile size and SPR AQ-3 minimizes soil burn severity. The potential for erosion to occur at non-shaded fuel breaks is addressed in SPR GEO-5 requires stormwater to be drained via water breaks which would decrease the potential for channelized erosion down the fuel break.

There are certain treatment activities proposed under the CalVTP that are more likely to take place in certain areas based on vegetation (fuel) type. Table 2-4 in Chapter 2, “Program Description,” summarizes the relative likelihood of using a treatment activity based on the treatment and fuel type. In general, it is highly likely that mechanical treatments (relative to other treatment activities) would be utilized for all treatment types in tree fuel types as well as for WUI fuel reduction treatments in shrub fuel types. There is a moderate likelihood that mechanical treatments would be utilized to implement ecological restoration treatments in shrub fuel types, and to implement WUI fuel reducing treatments and fuel breaks in grass fuel types. There is a high likelihood that prescribed burning would most be utilized for ecological restoration treatments in grass fuel types, a moderate likelihood it would be utilized to implement fuel break and ecological restoration treatments in tree fuel types, and a moderate likelihood it would be utilized for fuel break treatments in shrub fuel types. Because erosion is more likely to occur in areas treated using mechanical treatment activities and prescribed burns, all treatment types implemented in grass fuel types, fuel breaks implemented in shrub fuel types, and fuel break and ecological restoration treatments implemented in tree fuel types are the most likely to be treated using treatment activities that could cause erosion.

Erosion and loss of topsoil could occur in geomorphic provinces dominated by shrub vegetation types (i.e., Southern Coast Range, Transverse Ranges, and Peninsular Ranges) because prescribed burning has the potential to result in high burn severity in shrub-dominated vegetation. This is addressed with SPR AQ-3 which minimizes soil burn severity. Mechanical treatments in shrub-dominated vegetation and in forested areas of the Coast Ranges, Sierra Nevada, Klamath Mountains and Cascade Range provinces would generally remove the majority of the vegetation in discrete areas to reduce fuels. Potential erosion would be minimized with implementation of SPR GEO-3 which requires stabilization of mechanically disturbed soil areas and SPR GEO-4 which requires erosion inspections.

In an area that is treated by prescribed burning, typically 70 percent of the vegetation remains which helps minimize erosion (CAL FIRE 2019). Additionally, vegetation usually regrows within a year (CAL FIRE 2019). Following a prescribed burn, CAL FIRE would minimize erosion around the perimeter of the burn or from installation of waterbars (SPR GEO-5).

Implementation of SPRs as described above would avoid and minimize any substantial soil erosion or loss of topsoil during treatment activities. This impact would be **less than significant**.

As described in Section 2, “Program Description,” one of the primary purposes of the CalVTP is to reduce wildfire risk in California. Catastrophic wildfires may occur if the vegetation in an area is not treated. If burn severity is high, increased overland flow and exposure of mineral soil can lead to rain splash, sheetwash, and rill erosion (Robichaud et al. 2010). While implementation of the CalVTP may result some erosion and loss of topsoil during treatments, the CalVTP is anticipated to reduce the occurrence and severity of wildfires that can result in substantial erosion and loss of topsoil. An analysis performed after the Clearwater fire in Idaho found that the “increase in sediment delivery associated with the proposed activities will likely be offset by the reduced risk of fire, the reduced severity of a fire should it occur, and the reduction in hillslope sediment delivery following a wildfire” (Lake Tahoe West Science Group 2018). Given the unpredictability of wildfire severity and the possible variability in acreage treated under the CalVTP, evaluating the effect of the CalVTP on wildfire-caused erosion is not possible, nor is it pertinent to determining the significance of this impact under CEQA. However, it is anticipated that the CalVTP would decrease the risk of erosion in areas that could otherwise be at substantial risk of erosion after burning in a high-severity wildfire.

##### Mitigation Measures

No mitigation is required for this impact.

Impact GEO-2: Increase Risk of Landslide

Removal of vegetation during treatments activities implemented under the CalVTP could affect the root structure in treated areas such that the stability of slopes and soils could decrease, which would increase the risk of landslide. Additionally, by removing vegetation, the soil water content could increase due to lack of uptake and transpiration by the vegetation. Higher soil water content could potentially destabilize slopes and increase the risk of landslide. Landslide risk would increase in areas with steeper slopes and where previous landslide has occurred. Implementation of SPRs GEO-3, GEO-4, GEO-7, and GEO-8 would avoid or minimize the risk of landslide resulting from CalVTP treatments. This impact would be **less than significant**.

Shallow-landsliding occurrence is more likely to occur in the mountainous portions of the Coast Ranges, Klamath Mountains, Transverse Ranges, and the Sierra Nevada relative to other geomorphic provinces mostly because the soil types and slope in these areas are more conductive to landsliding under certain circumstances in comparison to other areas. The highest susceptibility in the treatable landscape for deep-seated landsliding is in the Coast Ranges, Klamath Mountains, and Transverse Ranges provinces based on rock strength and slope (Willis et al. 2011) (Figure 3.7-3).

Removing vegetation during treatments implemented under the CalVTP could potentially increase the risk of landslide by removing root systems that stabilize slopes. This risk is addressed with SPR GEO-3 which requires stabilization of mechanically disturbed soil, SPR GEO-4 which requires erosion inspections, SPR AQ-3 which minimizes soil burn severity resulting in some vegetation remaining which retains root structures, SPR GEO-7 which minimizes erosion by prohibiting mechanical treatment on steep slopes, and SPR GEO-8 which requires that a RPF or licensed geologist to evaluate treatment areas with slopes greater than 50 percent for unstable areas. Removing vegetation could also potentially increase the risk of landslide by removing vegetation which no longer uptakes ground water thereby increasing water content of the soil and making soils more prone to sliding. The removal of forest cover decreases interception and transpiration, and in wetter areas, this generally increases annual water yields (Robichaud et al 2010). A rising groundwater table (“bottom up” saturation) within the saturated zone leads to a gradual growth of porewater pressure in the soil which leads to destabilization of slopes and can lead to failure of slopes (Bronnimann 2011). This risk is also addressed with the SPRs mentioned above.

Moderate to high severity wildfire can greatly increase the likelihood of debris sliding and debris flows (Haas et al. 2017) as well as loss of soil hydrologic function by sealing pores, degradation of soil structure and productivity. Wildfire can significantly alter the hydrologic response of a watershed to the extent that even modest rainstorms can produce dangerous flash floods and debris flows. In existing models, the primary variable connecting a wildfire and a subsequent debris flow is the amount of a watershed that burns with moderate to high severity (Haas et al. 2017). Fires that burn with low severity, including prescribed burns implemented under the CalVTP, can maintain soil cover, mineralize important nutrients from plant matter stored on the soil surface, reduce fuel loads leading to possible future high burn severity, and stimulate herbaceous vegetation helping to facilitate nutrient cycling. Prescribed burns implemented under the CalVTP would, under most circumstances, retain 70 percent of the vegetation in a treatment area.

Implementation of SPRs as described above would avoid and minimize the risk of landslide from treatments implemented under the CalVTP. Therefore, this impact would be **less than significant**.

As described above, moderate to high severity wildfire can greatly increase the risk of landslides, including the likelihood of debris sliding and debris flows. One of the primary purposes of the CalVTP is to reduce wildfire risk in California. Given the unpredictability of wildfire severity and the possible variability in acreage treated under the CalVTP, evaluating the effect of the CalVTP on wildfire-caused landsliding is not possible, nor is it pertinent to determining the significance of this impact under CEQA. However, it is anticipated that the CalVTP would decrease the risk of landslide in areas that could otherwise be at substantial risk of landslide after burning in a high-severity wildfire.

##### Mitigation Measures

No mitigation is required for this impact.

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