C. GEOLOGY, SOILS, AND SEISMICITY

This section describes geologic conditions in the Wildfire Hazard Reduction and Resource Management Plan (Plan) Study Area based on information obtained during a site reconnaissance and review of published and unpublished geologic reports and maps. This section assesses potential impacts from earthquake-induced fault rupture, ground shaking, landslides, slope stability, liquefaction, lateral spreading or erosion related to Plan implementation and identifies mitigation measures, if necessary.

1. Setting

The Study Area consists of 13 hillside and 7 shoreline parks and recreation areas under the jurisdiction of the East Bay Regional Park District (EBRPD), and is approximately 26 miles in length on its northwest-southeast axis and about 6.5 miles wide in the northeast-southwest direction. Elevations within the Study Area range from approximately 0.0 feet to 1,915 feet above mean sea level (msl).

The upland hillside parks are located in the northern two-thirds of the East Bay Hills, an area that stretches from San Jose to San Pablo Bay, behind the alluvial plains formed adjacent to and east of the San Francisco Bay. The East Bay Hills are part of the Northern California Coast Ranges and are located within California's Coast Ranges Geomorphic Province, a geologically young and seismically active region dominated by northwest-southeast trending ranges of low mountains and intervening structural basins forming valleys.[1] The East Bay Hills are only a few million years old and are compressed by tectonic forces between the Hayward and Calaveras faults. The geologic material of the East Bay Hills occurs in complex folds, with axes generally trending northwest.[2] The soils in the area are susceptible in varying degrees to landslides and erosion.

It should be noted that wildfire hazards are very low and fuel modification activities are not expected to be undertaken in the following shoreline parks: Eastshore State Park; Middle Harbor Shoreline Park; Robert W. Crown Memorial State Beach; and Martin Luther King Jr. Regional Shoreline. Additionally, Brooks Island Regional Shoreline is isolated from developed areas and fuel modification activities are not anticipated for the park as it does not present a fire hazard. As Plan activities will not be undertaken at these parks, they will not be specifically evaluated for geology, soils and seismicity hazards further in this discussion.

The three Shoreline Parks subject to the Plan—Point Pinole Regional Shoreline, Miller/Knox Regional Shoreline, and Eastshore State Park—are located on the alluvial plains along the eastern shore of the San Francisco Bay. Miller/Knox also includes some upland areas comprising undifferentiated bedrock that rise relatively steeply as a ridge running to the east of the park.

a. Topography. Most of the land within the hillside parks of the Study Area is moderately to very steeply sloped and includes ridgelines and interior valleys. Wildcat Creek (and its tributaries) is a significant hydrologic feature in Tilden and Wildcat Canyon Parks. Wildcat Creek flows to the north and out of the Study Area.[3,4] To the south, Lake Chabot is within the Study Area and has an elevation

[1] California Geological Survey, 2002, *California Geomorphic Provinces, Note 36,* California Dept. of Conservation.

[2] Sloan, Doris, 2006. *Geology of the San Francisco Bay Region,* University of California Press.

[3] USGS, 1959 rev. 1980. *Richmond Quadrangle 7.5' Topographic Map*, U.S. Department of the Interior.

of approximately 240 feet msl. Lake Chabot originated in 1879 and is a 315-acre reservoir behind a 135-foot tall earthen dam.[5] Just east of the Study Area is the San Leandro Reservoir with an elevation of approximately 460 feet msl. San Leandro Creek connects the two lakes and continues out of the Study Area west to the San Francisco Bay.[6,7]

The shoreline parks are near sea level, with relatively level topography near the shore and limited areas of elevation, such as the ridges within Miller/Knox Regional Shoreline, which rise steeply just behind the shore area to about 320 feet msl. Eastshore State Park rises in low steps or as relatively gentle slopes to elevations of about 10 to 20 feet msl. Point Pinole Regional Shoreline has areas of very low, terraced bluffs backed by relatively gentle slopes that build to inland knolls with elevations of up to about 105 feet msl.

b. Geology. The East Bay Hills are underlain by bedrock of the Franciscan Complex and Great Valley Group from the late Mesozoic (greater than 65 million years old) and mantled with Holocene surficial deposits (less than 10,000 years).[8] The development of the East Bay Hills is complex and ongoing, as they continue to rise in response to the tectonic forces generated by the San Andreas Fault Zone, in which the Hayward Fault is located. Younger sedimentary and volcanic layers overlie portions of the dominant Franciscan Complex and Great Valley Group, and are detailed in Table IV.C-1. Point Pinole is at the northwestern end of the Study Area and comprises an extension of a northwest-trending ridge composed of the same Upper Tertiary rock as the East Bay Hills, and the southeast shore is parallel and overlies the Hayward Fault. To the west of the Hayward fault, the lowland areas fronting San Francisco Bay (i.e., the area of Miller/Knox) are composed of a quaternary alluvium with occasional outcrops and rises of Franciscan Complex bedrock. Most of the low lying shoreline, particularly in the vicinity of the shoreline parks, is composed of a layer of artificial man-made fill (see discussion of Urban Land below) over Bay Mud.[9]

The Franciscan Complex consists of a mixture of sandstone, shale, basalt, and chert that have been subjected to various degrees of high-pressure metamorphism. Many exposures of Franciscan Complex consist of isolated blocks of hard rock in a matrix of sheared clay. Soil creep, debris flows, and landslides are common in areas underlain by the Franciscan Complex. The Franciscan Complex is separated from the Great Valley Group by the Coast Range thrust fault.[10]

---

[4] USGS, 1959 rev. 1980, *Oakland East Quadrangle 7.5' Topographic Map*, U.S. Department of the Interior.

[5] Beggs, Jacqueline, 1997. *History Walk At Lake Chabot*, East Bay Regional Parks District.

[6] USGS, 1959 rev. 1980, *Hayward Quadrangle 7.5' Topographic Map*, U.S. Department of the Interior.

[7] USGS, 1995, *Las Trampas Ridge Quadrangle 7.5' Topographic Map*, U.S. Department of the Interior.

[8] Graymer, R. W., 2000. *Geologic Map and Map Database of the Oakland Metropolitan Area, Alameda, Contra Costa, and San Francisco Counties, California.* USGS MF-2342v1.

[9] Sloan, Doris, 2006, op. cit.

[10] URS Corporation, 2003. Final Environmental Assessment for the East Bay Regional Park District Vegetation Management Projects, Alameda and Contra Costa Counties, California. HMGP #919-515-24. Prepared for the Federal Emergency Management Agency. April.

Table IV.C-1: Distribution of Primary Surface Geology in the Study Area

Name of Formation	Relative Landslide Susceptibility Rating	Approximate Percentage of Study area
Redwood Canyon Formation (Late Cretaceous)—Massive, distinctly bedded sandstone with minor interbedded siltstone	High	17.7%
Orinda Formation (Miocene) —Conglomerate, sandstone, siltstone. Nonmarine with abundant clasts of rocks from the Franciscan Complex.	High	15.5%
Unnamed sedimentary and volcanic rocks (Miocene and Pliocene) —Includes marine and nonmarine conglomerate, sandstone, and siltstone, as well as basalt and limestone mapped locally.	Varies	13.8%
Joaquin Miller Formation (Late Cretaceous) —Shale with minor sandstone.	Low	9.2%
Oakland Conglomerate (Late Cretaceous) —Conglomerate containing mainly silicic volcanic clasts and massive biotite-rich quartz sandstone.	Medium	9.2%
Moraga Formation (Miocene) —Basalt and andesite flows, minor rhyolite tuff. Interflow sedimentary rocks mapped locally.	Medium	6.7%
Shephard Creek Formation (Late Cretaceous) —Mainly shale with minor sandstone.	High	6.1%
Surficial deposits (undivided Pleistocene and Holocene)	Varies	3.0%
Claremont Chert (Miocene) —Laminated and bedded diatomaceous chert, minor brown shale and white sandstone. Interbedded sandstone mapped locally.	Low	2.8%
Water	N/A	2.3%

Sources: Results based on GIS analysis of data layers provided by USGS:
Preliminary geologic map emphasizing bedrock formation in Contra Costa County, California: A digital database, Open-File Report 94-622.
Preliminary geologic map emphasizing bedrock formations in Alameda County, California: A digital database, Open-File Report 96-252.
Relative landslide susceptibility adapted from information in: Map and map database of susceptibility to slope failure by sliding and earthflow in the Oakland area, California, Miscellaneous Field Studies Map MF-2385.

The Great Valley Group consists of alternating sequences of sandstone, siltstone, and claystone. Areas underlain by Great Valley claystone and siltstone are prone to landsliding and soil creep. Areas underlain primarily by sandstone are relatively more stable but may be susceptible to rockfalls and landslides where the strata are at an unfavorable orientation.[11]

c. Soils. Soil is generally defined as the unconsolidated mixture of mineral grains and organic material that mantles the land surface. Soils can develop on unconsolidated sediments and weathered bedrock. The characteristics of soil reflect the five major influences on their development: topography, climate, biological activity, parent (source) material, and time. The Study Area is mantled by surface soils that reflect the characteristics of the underlying materials on which the soil is developed.

The upland portions of the Study Area east of the Hayward fault are mostly on hillsides and near the tops of ridges. The soils in these areas are generally shallow, and the erosion hazard is generally high

[11] URS, 2003. op. cit.

to very high.[12] Vegetation tends to reduce the potential for shallow erosion. The National Resource Conservation Service (NRCS) soil survey catalogues at least 30 different soil varieties with the Study Area plus variations within these based on slope steepness. However, these can be grouped into three 'associations' with similar characteristics.

Along the western foothills the primary association is Xerorthents – Maymen – Millsholm, which are steep to very steep, well drained, and somewhat excessively drained soils that have various textures. These soils are in hills at an elevation of 200 to 1,500 feet msl and have slopes of 30 to 75 percent. Xerorthents consist of soil materials that may have been altered by cutting or filling related to development. Permeability is moderate with rapid runoff characteristics and a high erosion hazard. It is recommended that permanent vegetation cover be maintained with careful water management procedures, and minimal irrigation water should be used to prevent mudflows. [13] In addition, the upland portions of Miller/Knox are mapped as Millsholm Loam with slopes of 50 to 70 percent. This soil is very shallow, less than 12 inches, and has a sever erosion rating when disturbed. The lowlands around the lagoon are mapped as Reyes Silty Clay, while the surface soils of the point and south end of the park are mapped as Urban Land.

A second soil association in the Study Area occurs on the upper southeastern and eastern slopes of the Study Area around and north of Lake Chabot. The Millsholm – Los Gatos – Los Osos association are moderate sloping to very steep soils overlying moderately hard sedimentary rocks with elevations of 600 to 2,500 feet msl. All associated soils are well to excessively drained. Local landslides occur within both Los Osos and Millsholm soils but are more frequent in the finer grained Los Osos soils. In some areas the soils of this association are moderately eroded and have been subject to frequent landslides.[14]

A third soil association with a significant presence occurs in the northeastern Study Area. The Gilroy – Vallecitos association consists of moderately steep to very steep well-drained loams and clay loams that were formed in material weathered from interbedded sedimentary, meta-sedimentary and igneous rocks of upland areas. These soils frequently overlay igneous bedrock and vary from shallow to moderately deep with slopes varying from 15 to 75 percent. Elevations range from 500 to 3,000 feet msl. [15]

The shoreline parks are generally mapped to have a soil type from the miscellaneous category of Urban Land. Urban Land, also known as man-made fill, can be composed of varying amounts of natural soil materials, construction debris, dredging materials, municipal solid waste, and other materials.[16] Fill can vary widely in depth and make-up, and is generally not characterized for quality and suitability due to this wide variation.

---

[12] Sloan, Doris, 2006. op. cit.

[13] Soil Conservation Service, 1981. *Soils Survey of Alameda County, California, Western Part,* US Department of Agriculture.

[14] Soil Conservation Service, 1966. *Soils Survey of Alameda County, California (Eastern Part),* US Department of Agriculture.

[15] Soil Conservation Service, 1977. *Soils Survey of Contra Costa County, California,* US Department of Agriculture.

[16] Scheyer, J.M., and K.W. Hipple, 2005. *Urban Soil Primer.* United States Department of Agriculture, Natural Resources Conservation Service, National Soil Survey Center, Lincoln, Nebraska (http://soils.usda.gov/use).

Point Pinole, which is a naturally occurring rise, is mapped to be primarily of the Tierra Loam Soil type. This soil forms on fluvial terraces from alluvium originating from sedimentary rock and is moderately well drained, giving it a low water capacity. Undisturbed, it has only a slight erosion tendency, but in areas of roads and trails or otherwise disturbed the erosion hazard can be moderate to severe, depending on the slopes present.

d. Seismic Conditions. The Study Area is located in the seismically-active San Francisco Bay Area. The main feature generating seismic activity in the region is the tectonic plate boundary between the North American and Pacific plates. Locally, this boundary is referred to as the San Andreas Fault Zone (SAFZ), which includes the San Andreas Fault and numerous other active faults. The SAFZ includes numerous active faults found by the California Division of Mines and Geology (now named California Geological Survey) under the Alquist-Priolo Earthquake Fault Zoning Act (A-PEFZA) to be "active" (i.e., to have evidence of fault rupture in the past 11,000 years). The purpose of the A-PEFZA is to prohibit the location of most structures for human occupancy across the traces of active faults and thereby mitigate the hazard of fault rupture. Some of the major active faults within the SAFZ include the San Andreas, Hayward, Rodgers Creek, Calaveras, San Gregorio-Seal Cove, Maacama, West Napa, Green Valley, Concord, Greenville, and Calaveras faults. The closest fault to the Study Area is the Hayward Fault, which parallels the East Bay Hills and intersects portions of several of the Study Area parks.

In a fact sheet published in 2003, the U.S. Geological Survey estimated that there was a 62 percent probability that, between 2003 and 2032, a 6.7 or greater magnitude earthquake will occur in the San Francisco Bay Region. The probability of a 6.7 magnitude or greater earthquake occurring along individual faults was estimated to be 21 percent along the San Andreas Fault, 10 percent along the San Gregorio Fault, 27 percent along the Hayward-Rodgers Creek Fault, and 11 percent along the Calaveras Fault.[17]

e. Seismic and Geologic Hazards. This section discusses surface rupture, ground shaking, liquefaction, and expansive soils.

EBRPD lands are located in a region of high seismicity. The entire area would experience strong ground shaking in the event of an earthquake. Low-lying areas underlain by soft soils would tend to have more intense shaking than areas underlain by bedrock. However, strong ground shaking is a substantial hazard throughout the region. Strong ground shaking can trigger landslides on hillsides and cause liquefaction of saturated granular soils. Table IV.C-2 lists the major faults, their approximate distance from EBRPD lands, and their maximum credible earthquakes.

[17] USGS, 2003, *Earthquake Probabilities in the San Francisco Bay Region: 2002 to 2032 – A Summary of Findings*, Open File Report 03-214.

Table IV.C-2: Major Seismic Sources near the EBRPD Study Area

Fault	Type of Fault	Distance from Parks (miles)	Maximum Credible Earthquake (M_W)
Hayward	RL strike-slip	1 (average)	7.5
Calaveras	RL strike-slip	5	7.5
Concord	RL strike-slip	6	6.5
San Andreas	RL strike-slip	20	8.0
Mt. Diablo Thrust	Thrust	12	6.9 [a]
Greenville Fault	RL strike-slip	18	7.75
Coast Ranges – Sierran Block Boundary	Thrust	24	7.0

[a] USGS, 2003. *Earthquake Probabilities in the San Francisco Bay Region: 2002-2031, OFR 03-214.* US DOI.

RL = right lateral

M_W = moment magnitude

Source: Mualchin, Lalliana, 1996. *A Technical Report to Accompany the Caltrans California Seismic Hazard Map 1996 (Based on Maximum Credible Earthquakes),* Caltrans Engineering Service Center, Office of Earthquake Engineering, Sacramento, CA. July.

(1) Surface Rupture. Surface rupture occurs when the ground surface is broken due to fault movement during an earthquake. The location of surface rupture generally can be assumed to be along an active major fault trace. The Hayward fault zone is oriented roughly parallel to and near the western edge of the Study Area. The current version of the Alquist-Priolo mapping indicates that the Alquist-Priolo zone crosses some portions of the Study Area.[18] Therefore, potential for fault rupture in the Study Area is possible.

(2) Ground Shaking. Ground shaking refers to all aspects of motion of the earth's surface resulting from an earthquake and is normally the major cause of damage in seismic events. The extent of ground shaking is controlled by the magnitude and intensity of the earthquake, distance from the epicenter, and local geologic conditions. Magnitude is a measure of the energy released by an earthquake; it is assessed by seismographs that measure the amplitude of seismic waves.[19] Intensity is a subjective measure of the perceptible effects of seismic energy at a given point and varies with distance from the epicenter and local geologic conditions. The Modified Mercalli Intensity Scale (MMI) is the most commonly used scale for measurement of the subjective effects of earthquake intensity, and is shown in Table IV.C-3. Intensity can also be quantitatively measured using accelerometers (strong motion seismographs) that record ground acceleration at a specific location, which is a measure of force applied to a structure under seismic shaking.

[18] California Department of Conservation, 1999, *Fault-Rupture Hazards Zones in California, Special Publication 42.*

[19] In the past, the common standard for measurement of magnitude (M_L) by geologists and earthquake seismologists was the Richter Scale. However, due to limitations of the instrumentation used to measure Richter magnitude, moment magnitude (M_W) is now commonly used to characterize seismic events. Moment magnitude is determined from the physical size (area) of the rupture of the fault plane, the amount of horizontal and/or vertical displacement along the fault plane, and the resistance of the rock type along the fault to rupture. The moment magnitude can be calculated following an earthquake or estimated for an expected earthquake if the fault rupture area and displacement and rock properties can be estimated accurately. Therefore, the magnitudes of expected earthquakes in the San Francisco Bay Area are reported as moment magnitudes.

Table IV.C-3: Modified Mercalli Scale[a]

	Intensity	Effects	v,[b] cm/s	g[c]
M[d]	I.	Not felt. Marginal and long-period effects of large earthquakes.		
3	II.	Felt by persons at rest, on upper floors, or favorably placed.		
	III.	Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.		0.0035-0.007
4	IV.	Hanging objects swing. Vibration like passing of heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing motor cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV wooden walls and frame creak.		0.007-0.015
	V.	Felt outdoors; direction estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.	1-3	0.015-0.035
5	VI.	Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church, school). Trees, bushes shaken (visibly, or heard to rustle - CFR).	3-7	0.035-0.07
6	VII.	Difficult to stand. Noticed by drivers of motor cars. Hanging objects quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices (also unbraced parapets and architectural ornaments - CFR). Some cracks in masonry C. Waves on ponds; water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.	7-20	0.07-0.15
	VIII.	Steering of motor cars affected. Damage to masonry C; partial collapse. Some damage to masonry B; none to masonry A. Fall of stucco and some masonry walls Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.	20-60	0.15-0.35
7	IX.	General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. (General damage to foundations - CFR.) Frame structures, if not bolted, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground. In alluviated areas sand and mud ejected, earthquake foundations, sand craters.	60-200	0.35-0.7
8	X.	Most masonry and frame structures destroyed with their foundations. some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.	200-500	0.7-1.2
	XI.	Rails bent greatly. Underground pipelines completely out of service.		>1.2
	XII.	Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.		

[a] From Richter (1958).
[b] Average peak ground velocity, centimeters per second (cm/s).
[c] Average peak acceleration (away from source).
[d] Richter magnitude correlation.

<u>Note</u>: *Masonry A, B, C, D.* To avoid ambiguity of language, the quality of masonry, brick or otherwise, is specified by the following lettering (which has no connection with the conventional Class A, B, C construction).

- *Masonry A:* Good workmanship, mortar, and design, reinforced, especially laterally, and bound together by using steel, concrete, etc; designed to resist lateral forces.
- *Masonry B:* Good workmanship and mortar, reinforced, but not designed to resist lateral forces.
- *Masonry C:* Ordinary workmanship and mortar; no extreme weaknesses such as non-tied-in corners, but masonry is neither reinforced nor designed against horizontal forces.
- *Masonry D:* Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.

A 6.9 (M_W) magnitude event on the nearby active North and South Hayward fault could be capable of generating very violent seismic shaking (MMI X) in the Study Area.[20] The San Andreas Fault is considered capable of generating a magnitude 7.9 (M_W) earthquake (similar to the 1906 San Francisco quake)[21] that could also generate moderate seismic shaking (MMI VI) in the Study Area. To the north, the Rodgers Creek fault and North Hayward could produce a 6.6 (M_W) event that could result in violent (MMI IX) shaking in the Study Area.[22]

Estimates of the peak ground acceleration have been made for the Study Area based on probabilistic models that account for multiple seismic sources. Under these models, consideration of the probability of expected seismic events is incorporated into the determination of the level of ground shaking at a particular location. The expected peak horizontal acceleration (with a 10 percent chance of being exceeded in the next 50 years) generated by any of the seismic sources potentially affecting the Study Area is estimated by the California Geological Survey at about 0.7g.[23] This level of ground shaking in the Study Area is a potentially-significant hazard.

Liquefaction is the temporary transformation of loose, saturated granular sediments from a solid state to a liquefied state as a result of seismic ground shaking. In the process, the soil undergoes transient loss of strength, which commonly causes ground displacement or ground failure to occur. Since saturated soils are a necessary condition for liquefaction, soil layers in areas where the groundwater table is near the surface have higher liquefaction potential than those in which the water table is located at greater depths. Regional liquefaction hazard mapping indicates that the majority of the upland Study Area is rated very low for liquefaction hazard, the exception being some small areas near Wildcat and San Leandro Creeks.

Low-lying areas near the shore of the San Francisco Bay composed of fill over Bay Mud, in addition to areas of Point Reyes Clay, are rated moderate to high for liquefaction potential.[24]

Lateral spreading is a form of horizontal displacement of soil toward an open channel or other “free” face, such as an excavation boundary. Lateral spreading can result from either the slump of low-cohesion unconsolidated material or, more commonly, by liquefaction of either the soil layer or a subsurface layer underlying soil material on a slope, resulting in gravitationally-driven movement.[25] Earthquake shaking leading to liquefaction of saturated soil can result in lateral spreading where the soil undergoes a temporary loss of strength. The upland Study Area topography is gently rolling to steeply sloped and includes creeks or other open bodies of water. The Study Area is generally not susceptible to liquefaction hazards; therefore, the risk of lateral spreading is considered to be potentially low in the upland areas. In the shoreline parks, however, those areas adjacent to the shore and underlain by fill (Urban Land) and Bay Mud or Point Reyes Clay soils are subject to a lateral

[20] Association of Bay Area Governments (ABAG), 2005. http://www.abag.ca.gov/bayarea/eqmaps/pickcity.html

[21] U.S. Geological Survey, California Integrated Seismic Network Shake Map Working Group, 2004. Website: http://quake.wr.usgs.gov/research/strongmotion/effects/shake/about.html#scenario.

[22] Association of Bay Area Governments (ABAG), 2005. op. cit.

[23] California Geological Survey, 2003. Probabilistic Seismic Hazards, http://www.consrv.ca.gov/cgs/rghm/pshamap/

[24] Association of Bay Area Governments (ABAG), 2001. Liquefaction Hazard Map for SF East Bay.

[25] Rauch, Alan F., 1997, *EPOLLS: An Empirical Method for Predicting Surface Displacements due to Liquefaction-Induced Lateral Spreading in Earthquakes*, Ph. D. Dissertation, Virginia Tech, Blacksburg, VA.

spreading hazard that will mirror the liquefaction hazard, and open trenches or excavations may present opportunities for a lateral spreading hazard to occur.

(3) Expansive Soils. Expansion and contraction of volume can occur when expansive soils undergo alternating cycles of wetting (swelling) and drying (shrinking). During these cycles, the volume of the soil changes markedly. As a consequence of such volume changes, structural damage to buildings and infrastructure may occur if the potentially expansive soils were not considered in project design and during construction. Most of the Study Area is located on steep slopes with shallow loam-based soils. The soil types are generally noted to have low shrink/swell potential.[26] Soils with a high clay content, such as those found in alluvial deposits near the Bay, may be prone to expansion and shrinking in response to changing moisture levels. These changes tend to occur slowly enough such that catastrophic building failures are not likely, but these changes can cause buckling or cracking in flatwork, cracks in structure walls, and settlement of foundations.

(4) Slope Stability. Slope failure can occur as either rapid movement of large masses of soil ("landslide") or slow, continuous movement ("creep"). The primary factors influencing the stability of a slope are: 1) the nature of the underlying soil or bedrock; 2) the geometry of the slope (height and steepness); 3) rainfall; and 4) the presence of previous landslide deposits. The Study Area is approximately 12,000 acres in size; of this amount, over 5,000 acres are on terrain that is considered "mostly landslides." Areas categorized as "mostly landslides" consist of mapped landslides, intervening areas narrower than 1,500 feet, and narrow borders around landslides. Many of these are historical, however any area that contains landslides constitutes a potential slope stability hazard.[27]

(5) Settlement and Differential Settlement. Differential settlement or subsidence could occur if improvements were built on low-strength foundation materials (including imported fill) or if improvements straddle the boundary between different types of subsurface materials (e.g., a boundary between native material and fill). While differential settlement generally occurs slowly enough that its effects are not dangerous to inhabitants, it can cause significant building damage over time.

f. Regulatory Context. This section describes the regulatory setting for geology, soils and seismicity.

(1) State and Federal Policies. Regulatory policies in effect in the Study Area related to geology, soils, and seismicity are primarily written to protect life and property from hazards related to the effects of a substantial earthquake event on development. The purpose of the A-PEFZA is to prohibit the location of most structures for human occupancy across the traces of active faults and thereby mitigate the hazard of fault rupture. The vegetation management recommendations included in the Plan would not include the development or construction of structures for human habitation; therefore, the restrictions imposed by the A-PEFZA are not applicable to Plan activities. The level of active seismicity resulted in classification of the region as Seismic Zone 4 (the highest risk category) in the Uniform Building Code (UBC). However, no structures are proposed as part of this Plan.

[26] Soil Conservation Service, 1971. op. cit.

[27] USGS, 1997, *Summary Distribution of Slides and Earth Flows in the San Francisco Bay Region, California*. OFR 97-745c

Contra Costa County and Alameda County General Plan Safety Elements address safety issues related to development and construction on properties affected by slope stability and earthquake-related hazards. These Safety Elements generally would not apply, as no development is proposed as part of the Plan.

(2) EBRPD Policies. The following policy from the 1997 EBRPD Master Plan applies to geology, soils, and seismicity:

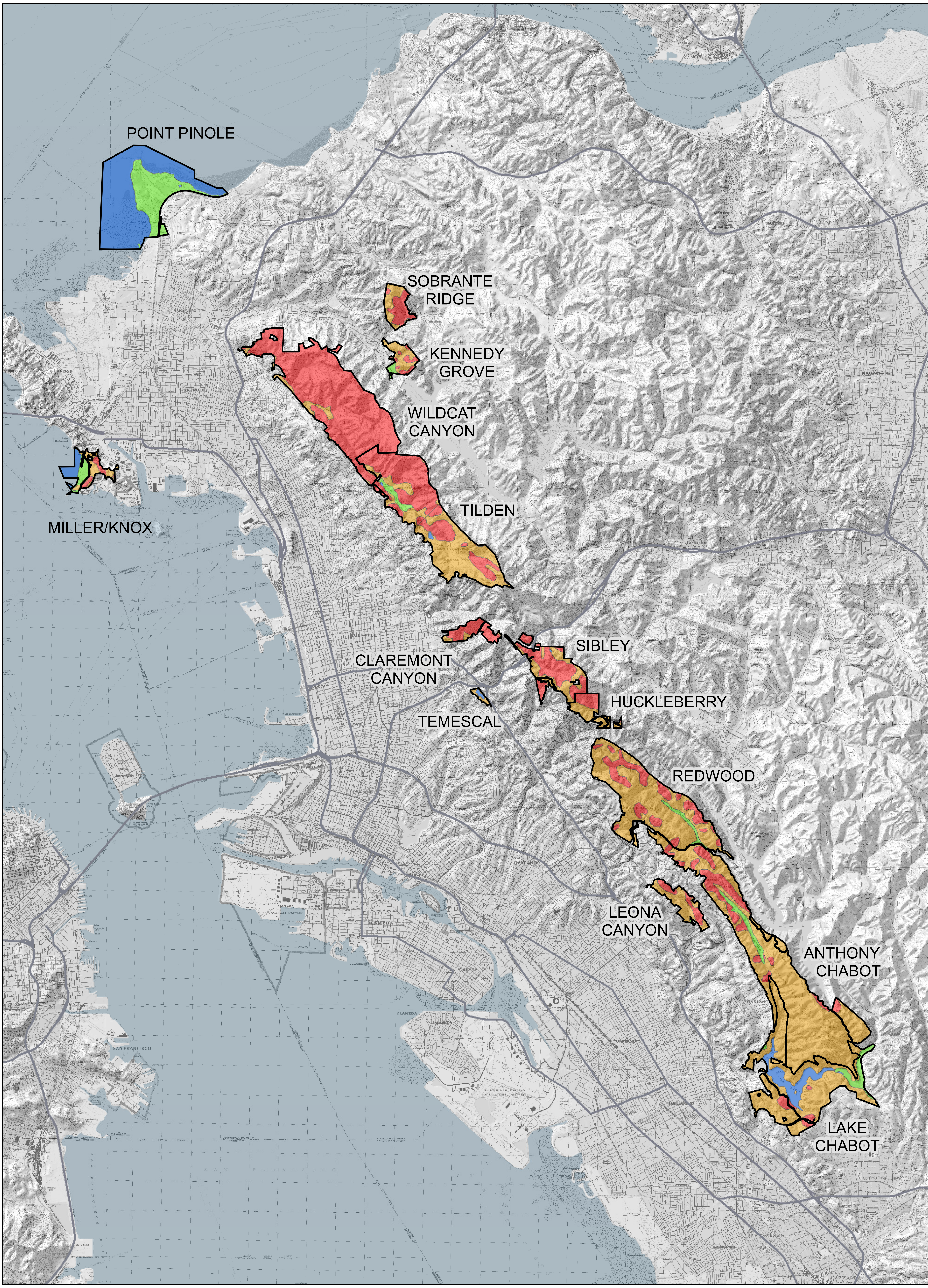
> The District will identify existing and potential erosion problems and take corrective measures to repair damage and mitigate causative effects. The District will manage the parks to assure that an adequate cover of vegetation remains on the ground to provide soil protection. Where vegetative cover has been reduced or eliminated, the District will take steps to restore it, using native or naturalized plants adapted to the site. The District will minimize soil disturbance associated with construction and maintenance operations and avoid disruptive activities in areas with unstable soils, whenever possible. The District will arrest the progress of active gully erosion, where practical, and take action to restore these areas to stable conditions. The District will notify adjacent property owners of potential landslide situations on District lands to warn of potential risks and conform with applicable law, and will protect important geological and paleontological features from vandalism and misuse.

2. Impacts and Mitigation Measures

This section analyzes the impacts related to geology, soils and seismicity that could result from implementation of the Plan. The section begins with criteria of significance, which establish the thresholds for determining whether a project impact is significant. The latter part of this section presents the potential geology, soils and seismicity impacts associated with the proposed project. Mitigation measures are provided as appropriate.

a. Criteria of Significance. The project would have a significant impact related to geology, soils, and seismicity if it would:

- Expose significant numbers of people or structures to 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.
- Expose people or structures to major geologic hazards that could result in loss, injury, or death related to strong seismic ground shaking or seismic-related ground failure, including liquefaction or landslides.
- Result in substantial soil erosion or 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), creating substantial risks to life or property.



L S A

N

0 1 2
MILES

Distribution of Landslides and Earth Flows

- Mostly Landslide
- Few Landslides
- Flat Land or Areas of Gentle Slope
- Water
- Project Area

FIGURE IV.C-1

EBRPD Wildfire Hazard Reduction and Resource Management Plan EIR

Distribution of Landslides and Earth Flows

SOURCE: San Francisco Bay Region Landslide Folio, Open File Report 97-745 (USGS 1997)

I:\EBR0601\GIS\Maps\EIR\Geo\FigureIV.C-1_Distribubution of Landslides and Earth Flows.mxd (10/31/2008)

Back of IV.C-1

b. Less-than-Significant Geologic Impacts. Implementation of the Plan would not expose an increased number of people or structures to seismic hazards because the project would not build new structures or draw more people to the seismically-active East Bay region. The project would not affect, or be affected by, expansive soils because no new structures or infrastructure would be constructed that could be affected by these soils.

c. Potentially Significant Geologic Impacts. The project consists of different treatment options for fuels reduction and vegetation management. Some of the treatment options involve actions that could cause slope instability (or, more likely, exacerbate existing slope instability problems) and soil erosion. The project includes Best Management Practices (BMPs) designed to avoid or minimize the potential for vegetation management activities to cause soil erosion and impacts to water quality. These are discussed in the Hydrology and Water Quality section of this EIR. This discussion, which focuses on the project's effects on slope instability, assumes that erosion is adequately addressed by Plan policies and mitigation measures included in the Hydrology and Water Quality section and that erosion related to Plan actions would not increase slope instability relative to existing conditions.

Impact GEO-1: Fuel reduction activities may result in increased slope instability. (S)

Slope instability (which can result in landslides) is a concern because it can cause damage to infrastructure and buildings, and in some cases can even result in injuries or deaths. Landslides can also generate large quantities of easily-erodible material and therefore can impact runoff water quality and degrade downgradient habitats (e.g., gravel bed streams). The main factors that affect slope instability are slope steepness, soil type, underlying geologic material type and structure, vegetation, subsurface water content, and human activity (e.g., loading a slope with weight or excavating and undercutting the slope toe). Of these factors, implementation of the Plan could most effect vegetation, subsurface water content, and human activity, and therefore the following discussion focuses on these factors.

The types of activities proposed by the Plan, including vegetation removal and activities supporting the removal (e.g., grading) could affect slope stability in some locations. In some cases, vegetation removal would result in direct removal of root systems (e.g., pulling brush by the roots) or indirect loss of root systems by eventual decay (e.g., tree removal when stumps and roots are left behind but the tree is killed). Root systems tend to add cohesion to surface soils and reduce soil moisture content through evapotranspiration. Under most circumstances, most of the increase in landslide activity after a tree removal operation can be attributed to a decrease in slope cohesion resulting from root decay.[28]

Slope steepness is an important factor in slope instability. Slopes of 30 to 40 degrees (58 to 84 percent)[29] tend to be the most frequent sites for landslides.[30] However, other factors such as bedding plane orientation and properties of the geologic materials can play an important role, and landslides can occur on slopes outside this range.

[28] Rice, R.M., 1977, Forest Management to Minimize Landslide Risk, in: Guidelines for Watershed Management, FAO Conservation Guide, Rome, Italy, pp. 271-287.

[29] Slope is horizontal distance divided by vertical elevation, and the grade is 100 times the slope. So a slope of 1/1 (which is a 45 degree slope) would be a 100 percent grade.

[30] Rice, R.M., 1977, op.cit.

There are many different types of landslides, from shallow soil slips to deep-seated rotational failures and block slides. Shallow landslides and soil slips are often related to saturation of the shallow soils and surficial erosion processes. Many of these types of landslides would be prevented by the BMPs included in the Plan, as described in the Hydrology and Water Quality section of this EIR. Most moderate to large landslides would be more deep-seated, potentially with failure planes[31] of 10 feet or more in depth. One study of landslide characteristics of the Wildcat Canyon and Tilden Regional Parks indicated that the majority of the failure planes of earthflows in these areas were in excess of 15 feet below the surface.[32] While deep-seated landslides can be affected by surficial erosional processes, they could also be affected by other project actions related to vegetation removal, modification of the subsurface water content conditions, and grading and road building (i.e., human activity).

Five treatment options are discussed as part of the Plan, and each is geared toward different fuel reduction and resource management results. These treatment options include:

- Hand Labor. This option includes minor pruning, mulch and plastic cover application, weed pulling by hand, and shrub removal. These activities generally pose a low risk of impacts to slope instability due to the small scale of activity and ground disturbance. However, the potential still exists for this activity to remove soil-binding roots and change subsurface moisture conditions.
- Mechanical Treatment. This option generally includes grading, mowing, overstory removal, the use of landings, yarding, mechanical cutting, and mulching or chipping. These options often use large, tracked equipment that requires site preparation of their operating areas or access corridors (potentially including grading and/or road building). As such, these options pose a high risk of impacts to slope instability, particularly if conducted in locations already susceptible to landslides.
- Chemical Treatment. This option includes the application of herbicides to control the growth of vegetation. This option generally poses little-to-no risk of ground disturbance since the application would most often be by hand. However, the long-term effects of herbicides on vegetation cover and root systems could affect soil-binding roots and change subsurface moisture conditions.
- Prescribed Burning. This option includes the burning of larger areas (broadcast burning) or the burning of piles of cut brush (pile burning). This option poses little-to-no risk of ground disturbance, as ignition is done by hand application. However, post-fire erosion potential could be increased, and loss of vegetation and soil-binding root systems could reduce soil cohesion and change subsurface moisture conditions.
- Grazing. This option includes the use of grazing animals to reduce the fuel load in a given area, primarily grasslands or shrublands. This option generally poses a low risk of ground disturbance, although cattle wallows or the creation of animal trails may result in soil displacement and subsequent erosion.

[31] A landslide failure plane is the interface between the mobile material of the landslide and the stationary material of the underlying rock or soil.

[32] Seidelman Associates, 1989, The Effects of Land and Vegetative Management on the Stability of Slopes Along the Wildland/Urban Interface Wildcat Canyon and Tilden Regional Parks, August 1.

It should be noted that the potential for slope instability to be adversely affected for the long term would likely be increased if one or more major wildfires were to occur within the Study Area. Therefore, implementation of the Plan would likely reduce region-wide long-term slope instability related to potential post-fire conditions. In addition, the Plan includes the following guidelines that would reduce potential impacts related to vegetation management and landslides:

Plan Chapter II. Goals, Objectives and Guidelines.

1.3 Where active management, such as hand labor or mechanical treatments, prescribed burning, or fuel reduction zone construction is necessary to reduce wildfire hazard conditions, such efforts will be consistent with encouraging low fuel hazard, low maintenance, sustainable ecosystems. Pre-project site assessments will be conducted to identify and protect sensitive resources, as needed.

Plan Chapter IV. Fuel Reduction Methods Best Management Practices for Mechanical Treatment

- All mechanical treatment actions should use equipment, methods, and/or techniques that minimize ground disturbance and alterations to the existing soil structure.

Plan Chapter V. Vegetation Management Program Section C.3.a. Mature Eucalyptus Forest Fuel Reduction

- On treated areas susceptible to landslides, a geotechnical evaluation must be made on a case-by-case basis to determine the contribution of the root mass in deterring soil slippage or slumping and the potential impacts of vegetation type conversion on future landslide potential.
- Mechanical treatments should also only be utilized on slopes under 30 percent to avoid soil disturbances from heavy equipment use.

Each guideline listed above applies to all vegetation types. However, these policies are not adequate to ensure that potential increases in landslide activity related to implementation of the Plan is minimized to the full extent feasible. These policies do not provide adequate safeguards in all cases for the protection of existing structures (including wildland-urban interface residences). This potentially-significant impact can be mitigated to a less-than-significant level through the implementation of the following mitigation measure:

> <u>Mitigation Measure GEO-1</u>: Prior to implementation of any proposed vegetation removal activity, the recommended treatment area shall be screened for potential landslide activation risk using the following procedure:
>
> 1) EBRPD staff shall refer to:
>   - The most currently available landslide mapping from the United States Geologic Survey or the California Geological Survey for the Study Area (for example, the USGS, 1997, Summary Distribution of Slides and Earth Flows in the San Francisco Bay Region, California. OFR 97-745c);
>   - GIS slope steepness mapping for the Study Area.
>
> 2) If <u>all</u> of the following criteria are satisfied then no further action to address potential landslide activation would be required:
>   - The area to be treated within the recommended treatment area is located in an area listed as “stable”, “few landslides”, or equivalent;

- The average slope steepness of the recommended treatment area is less than 10 degrees (about 18 percent);
- There is no visible evidence of landslide activity (e.g., scarps, crooked trees, landslide-generated debris piles) within the recommended treatment area, as documented by a field reconnaissance; and
- There are no habitable structures within 100 feet of the toe of the slope downgradient of the recommended treatment area.

3) EBRPD staff shall determine on a case-by-case basis whether to retain a qualified professional (e.g., engineering geologist or geotechnical engineer) to conduct a geotechnical reconnaissance to evaluate the potential impacts of fuel reduction activities or vegetation type conversion on future landslide potential if:
   - Habitable structure(s) are located within 100 feet of the toe of the slope downhill of the treatment area, and
   - The prescribed treatment would include the use of heavy equipment or machinery and significant ground disturbing activities (i.e., this requirement would not apply to methods such as hand treatment, weed-eating, or chemical treatment), and one or more of the following conditions is identified:
     - The treatment area is listed as “unstable”, “many landslides” on applicable slope stability mapping, or
     - The average slope steepness of the treatment area is greater than 10 degrees (about 18 percent); or
     - There is visible evidence of landslide activity (e.g., scarps, crooked trees, landslide-generated debris piles) within the treatment area, as documented by a field reconnaissance,

All recommendations of the qualified professional (which may include avoidance of the proposed activity) shall be documented in writing, provided to EBRPD, and implemented. (LTS)