C. GEOLOGY, HYDROLOGY, AND SOILS

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NOTE 50
JANUARY 2013

Factors Affecting Landslides in Forested Terrain

Landslides and geomorphic features related to landsliding have been mapped by the Department of Conservation's California Geological Survey (CGS) on forest lands within numerous northern California watersheds under contract with the Department of Forestry and Fire Protection (CAL FIRE; see CGS Note 40). Landslide terminology used on the maps, and presented in this document, was developed in conjunction, and is compatible with, ongoing U.S. Forest Service (USFS) and California Department of Water Resources (DWR) mapping on forest lands. Descriptions presented here are excerpted from Bedrossian (1983). Definitions are consistent with those presented in Varnes (1978) and Cruden and Varnes (1996).

Factors affecting landslide potential are described according to the geological conditions, drainage characteristics, slope gradient and configuration, vegetation, removal of underlying support, and other conditions specific to each landslide related category (Figures 1-6). Management objectives and guidelines for each landslide-related category were developed primarily from field experience, recommendations made by CGS geologists during the Timber Harvesting Plan review process, practices currently required under the Z'Berg-Nejedly Forest Practice Act (Public Resources Code, 2013) and the California Forest Practice Rules (California Code of Regulations, 2013), and mitigation measures recommended in numerous geologic reports prepared for CAL FIRE, DWR, and the USFS. The guidelines address each landslide-related category and provide recommendations for forest practices related to road construction, logging, and site preparation.

LANDSLIDE TERMINOLOGY

Landslide terminology described here includes translational/rotational slide, earthflow, debris slide, debris flow/torrent track, debris slide amphitheater/slope, and inner gorge. The terms debris slide amphitheater and inner gorge refer to geomorphic features that were formed, in part, as a result of debris slide processes. Although they may be subject to continued debris slide activity, these features should not be misinterpreted as landslides. In addition, many landslides are, in reality, complex landslides subject to more than one type of landslide process. Accordingly, the management implications for such areas may be more complex than inferred here.

Most landslides are classified as active or dormant. The active or probably active slides are those which are presently moving or have recently moved, as indicated by the presence of distinct topographic slide features such as sharp barren scarps, cracks, and tipped (jackstrawed) trees. Major revegetation has not occurred on slides in the active category. Dormant slides show little evidence of recent movement; slide features have been modified by weathering and erosion and vegetation generally is well established. Although some large-scale landsliding may have developed under conditions different from today, the causes of failure may remain and movement could be renewed.

Translational/Rotational Slide

Definition. The translational/rotational slide is characterized by a somewhat cohesive slide mass and a failure plane that is relatively deep when compared to that of a debris slide of similar areal extent. The sense of the motion is linear in the case of a translational slide and is arcuate or "rotational" in the case of the rotational slide (Figure 1). Complex versions involving rotational heads with translation or earthflow downslope are quite

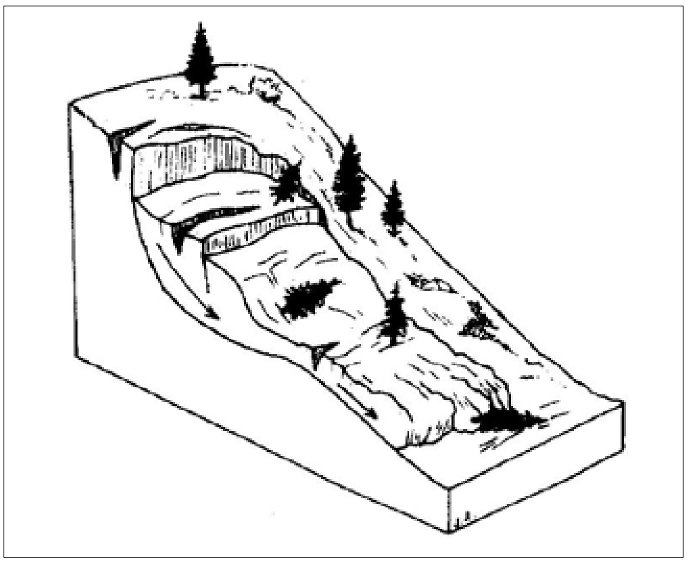

Figure 1. Diagrammatic sketch of a translational/rotational landslide. Drawing by Janet Appleby Richard Kilbourne and Thomas Spittler; modified from Varnes (1978)

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common. When movement occurs along a planar joint or bedding discontinuity, the translation may be referred to as a block glide.

Factors affecting landslide potential. Translational/rotational slides generally occur in relatively cohesive, homogeneous soils and rock. The soil mantle may be greater than 5 feet thick, but sliding is not restricted to the zone of weathering. Failure commonly occurs along bedrock bedding planes that are deep-seated and dip in the same direction as the slope surface. In saturated conditions, incompetent clayey bedrock material may fail under overburden weight and high pore pressures, resulting in a deep-seated rotational-type failure. Translational slides commonly are controlled structurally by surfaces of weakness such as faults, joints, bedding planes, and contacts between bedrock and overlying deposits.

Impaired drainage of slide deposits may be indicated at the surface by numerous sag ponds with standing water, springs, and patches of wet ground. Phreatophytic (wet site) vegetation may be widespread and jackstrawed trees are common. The concentric, downward movement of slide materials generally exposes a near vertical scarp in the head region and, occasionally, along the lateral margins of the slide. Slide materials are characterized by hummocky topography consisting of rolling, bumpy ground, frequent benches, and depressions. The toe of the slide may be steep where slide material has accumulated.

Although the removal of root support is not likely to affect the overall stability of the slide mass, large clear-cuts (relative to slide size) could raise the ground water table and induce instability. Steep crownscarps and margins of the translational/rotational slide and toe areas of large slides may be subject to debris sliding. The removal of toe materials on smaller slides may reactivate the entire slide area.

Management objectives. The major management objectives for mitigating potential problems on translational/ rotational slides are to: minimize water concentration on the steep scarp and lateral margins of the slides, avoid undercutting of the toe areas, minimize loading the upper bench of the slide, and avoid the activation of debris sliding on steep scarp and toe areas.

Management guidelines. To enhance stability, roads and landings across translational/rotational slides should be carefully located to unload the crown area and load the toe. Where possible, benches should be utilized. Surface water should be diverted away from the slide mass and scarp areas, and long-term maintenance should be considered in the planning of site specific drainage problems. In some situations, the engineered drainage of fill materials may be required, and cut and fill slopes should be seeded. In order to avoid creating debris sliding, debris slide measures for road construction should be applied to steep scarps and toes of large slides. Consultation with a Certified Engineering Geologist is recommended in melange terrain, where large slides show activity, and in the design of road drainage.

During logging, ground disturbance in the slide area should be minimized. Along the edge of the slides, vegetation removal and physical changes should be limited to avoid the concentration of water on slide materials and the endlining of logs from outside the slide area should be considered when feasible. On large slides, water courses immediately adjacent to the slide often form inner gorges and therefore should be considered as part of the potentially unstable slide mass. Because removal of vegetation could raise the groundwater level and result in the local concentration of surface water, the size of the slide and the amount and condition of existing vegetation should be considered in determining the size and type of proposed harvest. During site preparation, physical disturbances on scarp areas and toes, where debris sliding may occur, should be minimized and overall root mass should be maintained.

Earthflow

Definition. An earthflow is a landslide resulting from slow to rapid flowage of saturated soil and debris in a semiviscous, highly plastic state. After initial failure, the earthflow may move, or creep, seasonally in response to destabilizing forces.

Factors affecting landslide potential. Earthflows are composed of clay-rich materials that swell when wet, causing a reduction in intergranular friction. When saturated, the finegrained, clay-rich matrix may carry larger, more resistant boulders with them in slow, creeping movements.

Slide materials erode easily, resulting in gullying and irregular drainage patterns. The irregular, hummocky ground characteristic of earthflows is generally bare of conifers; grasslands and meadows predominate. Failures commonly occur on slopes that are gentle to moderate (Figure 2), although they may also occur on steeper slopes where vegetation has been removed. Undercutting of the toe of an earthflow is likely to reactivate downslope movement.

Management objectives. Because earthflow materials are so easily erodible, the main objective is to minimize the physical disturbance of the slide by 1) avoiding the concentration of water onto the slide mass and 2) avoiding deep cut slopes into slide deposits.

Management guidelines. Road construction across earthflows should be avoided whenever possible. Likewise, earthflows are not appropriate locations for landing sites. When conditions necessitate road construction, the road should be carefully designed and located to use benches, avoid wet areas and seeps, and where possible, follow contour. The road should be single lane in width and outsloped

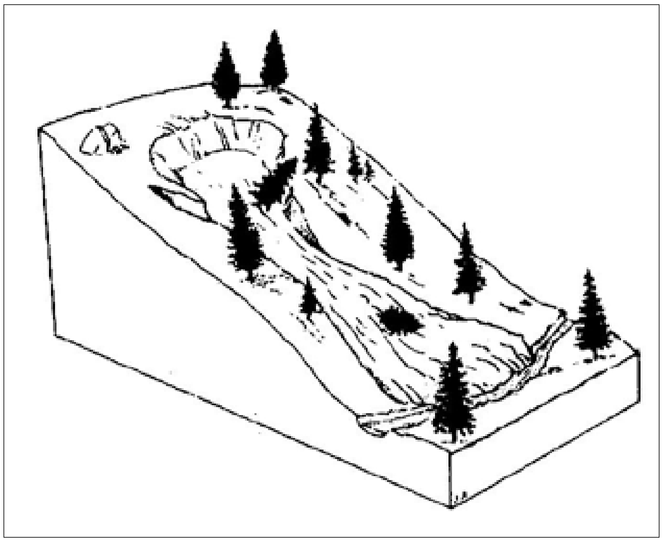

Figure 2. Diagrammatic sketch of an earthflow. Drawing by Janet Appleby and Richard Kilbourne; modified from Varnes (1978).

to avoid cutting into and concentrating water on slide materials. Areas exposed during road construction should be reseeded to minimize surface erosion. Winter construction and use is not advisable, and continued maintenance of drainage is recommended for major road construction across all earthflows.

During timber harvesting, ground disturbance should be minimized and the use of heavy equipment avoided. In logging areas adjacent to an earthflow, water should be drained from the slide to prevent gullying and reactivation of earthflow movement. Natural drainages on the earthflow should not be disrupted, for example, by the use of heavy equipment while being crossed to reach an adjacent logging site.

Debris Slide

Definition. A debris slide is characterized by unconsolidated rock, colluvium, and soil that has moved downslope along a relatively shallow translational failure plane (Figure 3). Debris slides form steep, unvegetated scars in the head region and irregular, hummocky deposits (when present) in the toe region. Debris slide scars are likely to ravel and remain unvegetated for many years. Revegetated scars can be recognized by the even-faceted nature of the slope, steepness of the slope, and the light bulb-shaped form left by many midand upper-slope failures.

Factors affecting landslide potential. Debris slides are most likely to occur on slopes greater than 65 percent where unconsolidated, non-cohesive, and rocky colluvium overlie a shallow soil/bedrock interface. The shallow translational slide surface is usually less than 15 feet deep. The probability of sliding is low where bedrock is exposed, except, where weak bedding planes and extensive bedrock joints and fractures parallel the slope.

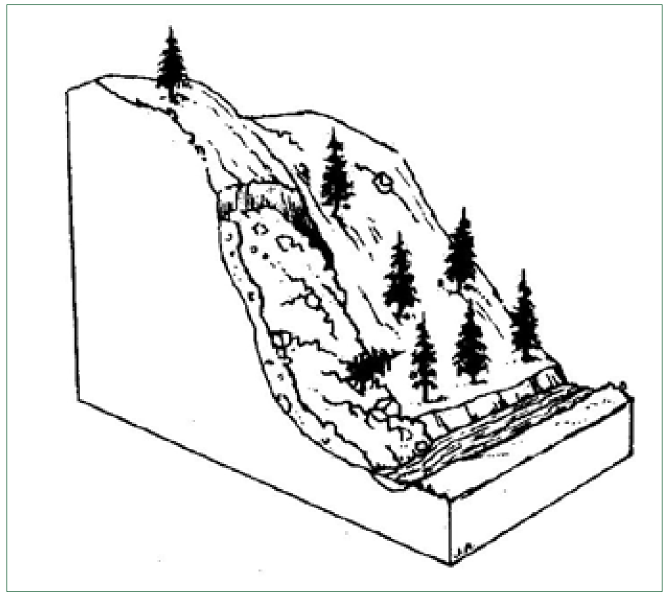

Figure 3. Diagrammatic sketch of a debris slide. Drawing by Janet Appleby and Richard Kilbourne; modified from Varnes (1978)

The presence of near surface bedrock creates a shallow, impervious slide plane that restricts the vertical movement of water and tends to concentrate subsurface water flow parallel to the slope. For this reason, sliding often occurs during high intensity storms. Springs may be present where water has concentrated along the slide plane. Because the removal of root support is likely to change the slope hydrology and shear strength of debris slide deposits, the vegetative cover where present is important to slope stability.

Management objectives. Because debris slides are characterized by unconsolidated materials above a shallow slide plane, the main management objectives are to: retain root support, minimize water flow along the soil/rock interface, avoid the undercutting of materials to the slide plane, and minimize the weighting of unconsolidated materials on steep slopes.

Management guidelines. Road construction across debris slides should be avoided where possible and existing roads used. Where active or potentially active slides on slopes over 65 percent must be crossed, the registered professional forester should consult a Certified Engineering Geologist in the preparation of the road design. Planning of the road should take into consideration a careful evaluation of both road and landing locations. Full bench cuts should be used across the slide where soils are most shallow and cut materials endhauled to minimize sidecast. If filling is necessary, fill materials should be retained during the road use and pulled before winter storms begin. Where possible, the road grade should be arched across the slide to drain water away from the slide. Where water must be drained onto the slide, energy dissipators should be used to reduce water impact on slide deposits. The undercutting of slide materials should be avoided in areas that are already buttressed; cribbing, retaining walls and/or riprap should be used where necessary. All small areas of unstable soil and debris should be removed from the roadcuts and cut and fill slopes seeded where vegetation will grow.

During logging, silvicultural practices should be designed to maintain maximum root support. In general, equipment exclusion zones and cable yarding are recommended. Site preparation burning should be designed to retain a maximum litter layer and some residual vegetation.

Debris Flow/Torrent Track

Definition. Debris flow and debris torrent tracks are characterized by long stretches of bare, generally unstable stream channel banks that have been scoured and eroded by the extremely rapid movement of water-laden debris (Figure 4). They commonly are caused by debris sliding or the failure of fill materials along stream crossings in the upper part of a drainage during high intensity storms.

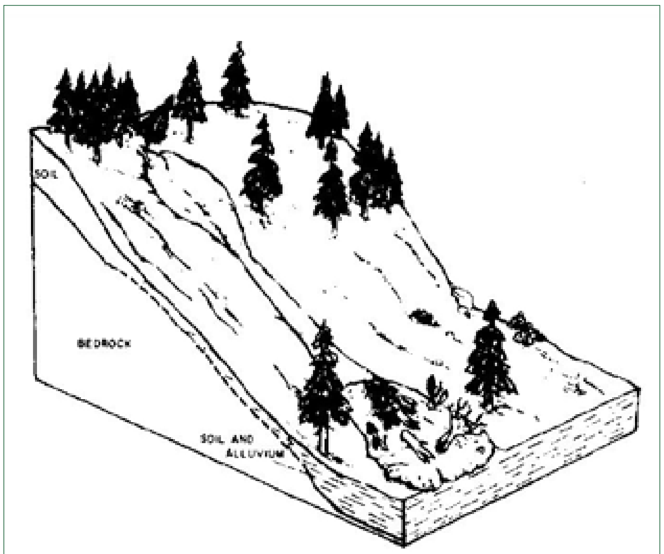

Figure 4. Diagrammatic sketch of a debris flow/torrent track. Drawing by Janet Appleby and Richard Kilbourne

Factors affecting landslide potential. Debris flow/torrent tracks are formed by the failure of water-charged soil, rock, colluvium, and organic material down steep stream channels. They are often triggered by debris slide movement on adjacent hill slopes and by the mobilization of debris accumulated in the stream channels themselves. Debris flows and torrents commonly entrain large quantities of inorganic and organic material from the stream bed and banks. Occasionally, the channel may be scoured to bedrock. When momentum is lost, scoured debris may be deposited as a tangled mass of large organic debris in a matrix of sediment and finer organic material. Such debris may be reactivated or washed away during subsequent events. The erosion of steep debris slide-prone streambanks below the initial failure may cause further failure downstream. The potential for failure is largely dependent upon the quantity and stability of soil and organic debris in a stream channel and the stability of adjacent hill slopes. The location of roads and landings upslope also affects landslide potential.

Management objectives. The main management objectives in mitigating areas containing debris flow/torrent tracks are to protect water quality and to avoid or minimize the possibilities of reactivating debris flow and debris torrent failures.

Management guidelines. Road and landing construction should be avoided across debris flow/torrent tracks. Where possible, scour-resistant crossings, such as low water crossings and rock fills, should be used.

In planning the harvesting of slopes adjacent to debris flow/torrent tracks, consideration should be given to the stability of the channel slopes. Soils exposed by logging operations adjacent to the tracks should be stabilized. Although an equipment exclusion zone around the track is recommended, the removal of logged debris below the stream transition line may be appropriate in some circumstances. A suitable overstory and understory should be left on slopes adjacent to the track.

Debris Slide Amphitheater/Slope

Factors affecting landslide potential. Debris slide amphitheaters and slopes are characterized by generally well vegetated soils and colluvium above a shallow soil/bedrock interface. The slopes may contain areas of active debris sliding or bedrock exposed by former debris sliding (Figure 5). Slopes near the angle or repose may be relatively stable except where weak bedding planes and extensive bedrock joints and fractures parallel the slope angle. Although the slopes often are smooth, steep (generally greater than 65 percent), and unbroken by benches, they are characteristically dissected by closely-spaced incipient drainage depressions. In many places, perennial channels within the amphitheaters and slopes are deeply incised with steep walls of rock or colluvial debris. The presence of bedrock or impervious material at shallow depths may concentrate subsurface waterflow, and springs may be present where permeable zones above the restrictive layer are saturated.

The presence of linear or teardrop-shaped, even-aged stands of trees, beginning at small scarps or spoon-shaped depressions, is indicative of former debris slide activity. Because soil and colluvial materials are shallow, the vegetative cover, where present, is important to slope stability and the removal of root support could change slope hydrology.

For these reasons, the intensity of road networks and the location of roads and drainage structures are particularly

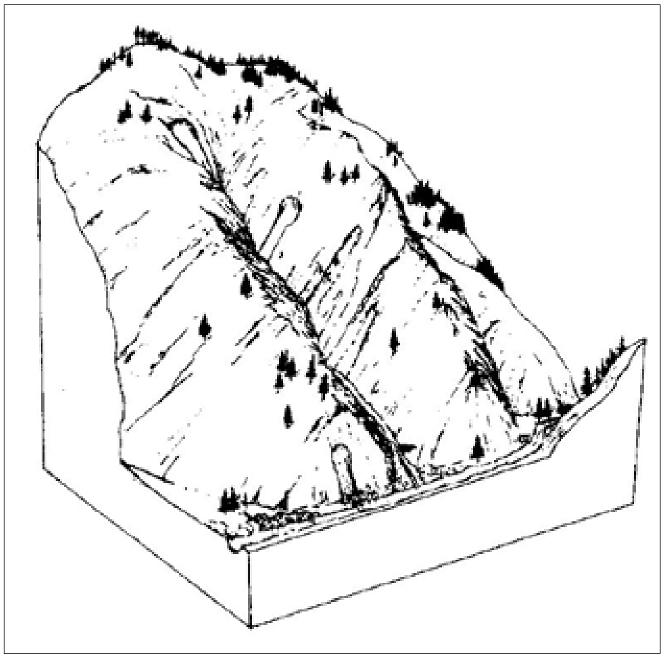

Figure 5. Diagrammatic sketch of a debris slide amphitheater and debris slide slopes. Drawing by Janet Appleby and Richard Kilbourne

important to slope stability in debris slide amphitheaters and on debris slide slopes. Areas adjacent to active slides have increased potential for sliding. The placement of fill materials on steep, unconsolidated upslope deposits also increases landslide potential.

Management objectives. The major management objectives in mitigating slope stability problems on debris slide amphitheaters and slopes are to: to retain root support, minimize water concentration in areas where soils are well-developed, and avoid large, continuous openings on steep slopes at any given period of time.

Management guidelines. Prior to road and landing construction, areas of active and potentially active debris slide movement should be identified. In areas of active and potentially active sliding, debris slide guidelines should be applied. In other areas where slopes are 65 percent or greater, the number and total length of roads should be minimized. Roads should also be located to avoid the crossing of active slides and the undercutting of buttressed slide materials.

During logging, a substantial vegetative cover should be retained by minimizing the size and continued downslope extent of vegetative openings and/or by using patch cuts. In areas with active sliding, equipment exclusion zones are recommended. On steep slopes, skyline and cable methods of logging should be used with a minimum number of blind leads. The amount of slash accumulated in deeply incised stream channels should also be minimized to reduce the chances of initiating debris flows and torrents.

During site preparation for replanting, burns should be designed to retain a maximum litter layer and residual vegetation. Equipment exclusion zones should be used around active slides.

Inner Gorge

Definition. An inner gorge is a geomorphic feature formed by coalescing scars originating from landsliding and erosional processes caused by active stream erosion. The feature is identified as that area of stream bank situated immediately adjacent to the stream channel, having a side slope of generally over 65 percent, and being situated below the first break in slope above the stream channel (Figure 6).

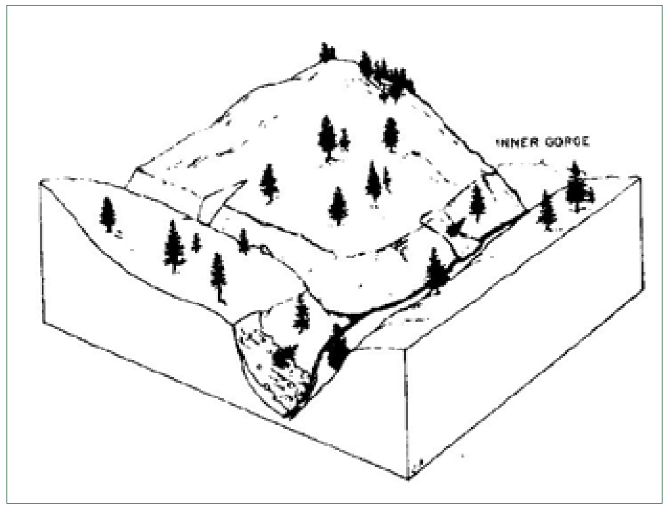

Figure 6. Diagrammatic sketch of the inner gorge. Drawing by Janet Appleby and Richard Kilbourne

Factors affecting landslide potential. Inner gorges are formed dominantly by debris slide processes that have been activated by the downcutting of stream channel bottoms. They commonly form along toes of large upslope landslides undercut by stream erosion. Where bedrock is exposed, the inner gorge may be stable. Where shallow, permeable, noncohesive soils and colluvium overlie impervious bedrock and/or slide plane materials, subsurface water flow may be concentrated along the steep streambank slopes and springs may be present. Slope stability is affected by high intensity storms and by the undercutting of stream banks by the rise in the stream water level. Roadcuts, as well as streambank erosion, are likely to activate or reactivate downslope movement. The addition of fill and/or concentration of water from roads and landings above the inner gorge could also increase landslide potential. Because unvegetated scars are likely to ravel, root support and vegetation are important to the overall slope stability.

Management objectives. The main objectives in mitigating slope stability problems in the inner gorge are to: protect water quality, protect riparian vegetation, and minimize the reactivation of debris slide failures.

Management guidelines. Where possible, road construction should be avoided within the inner gorge. Likewise, the inner gorge is an inappropriate location for landing sites. Where roads must cross the inner gorge, they should be located in rock gorge areas or other areas of stable ground, or structural supports should be used. Crossings should be engineered and designed for temporary use, that is, fill materials removed upon completion of logging and/or during the winter season. Water should be directed away from unstable inner gorge slopes and roads constructed along the upper break in slope should be full-benched and outsloped where possible to disperse water drainage and minimize failure of fill materials into the watercourse. Culverts installed within the inner gorge should be large enough to pass debris as well as water. When installed, the culverts should follow the longitudinal profile of the stream channel in order to minimize erosion of unstable stream banks. During logging, an equipment exclusion zone within the inner gorge is recommended. In addition, trees should be felled away from the stream channel. A suitable overstory and understory should be retained to provide root support and unmerchantable timber that could reach the stream should be removed or stabilized. Debris below the stream transition line should also be removed. Where possible, exposed soils should also be stabilized.

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NOTE 45
JANUARY 2013

Guidelines for Engineering Geologic Reports for Timber Harvesting Plans

The following guidelines were prepared by the Department of Conservation's California Geological Survey (CGS) in co-operation with the California Department of Forestry and Fire Protection (CAL FIRE), the State Mining and Geology Board, the State Board for Professional Engineers, Land Surveyors, and Geologists (BPELSG), and the State Board of Forestry. Note 45 was developed with input from representatives from over 30 governmental and professional organizations, universities, industry consultants and the environmental community. Significant comments were made by the Association of Engineering and Environmental Geologists, North Coast Regional Water Quality Control Board, National Marine Fisheries Service, Redwood National Park, and the U.S. Forest Service. The guidelines may be used by California Professional Geologists (PGs), California Certified Engineering Geologists (CEGs), or California Professional Geotechnical Engineers (GEs) when preparing engineering geological reports for Timber Harvesting Plans (THPs) on private, state, and local agency timberlands.

Purpose

Timber harvesting and its associated activities can affect public health and safety, listed species and their habitats, water quality, or public lands by activating landslides or increasing surface soil erosion. The purpose of these guidelines is to aid geologists and engineers in identifying and assessing the geologic framework of proposed timber harvesting operations to evaluate those effects.

An engineering geologic report prepared under these guidelines should assess how activities associated with timber harvesting could affect the physical environment, particularly with respect to sediment input to watercourses and lakes. The level of investigation conducted under these guidelines should be based on the potential risk to public health and safety, listed species and their habitats, water quality, or public lands. In some cases, portions of these guidelines may be modified or omitted due to the absence of given concerns or issues at the site; in other cases, additional geologic information may be required.

Report Contents

The engineering geologic report should be written for review by agencies and the public and be prepared so that Licensed Timber Operators can understand and implement specific mitigation measures. The report should include, at a minimum, the following information:

I. General Information

A. Timber Owner

B. Timberland Owner

C. Name of THP or other identifier

D. Location (also see section IX, b)

1. 7.5' U.S. Geological Survey (USGS) Topographic Quadrangle
2. Legal Description
   a. Township, Range, Section
   b. Assessors Parcel Number (optional)
3. County
4. Watershed
   a. River System from published USGS topographic maps
   b. Named tributary stream (from published topographic maps)
   c. Planning Watershed as defined by CAL FIRE (to be supplied by Registered Professional Forester (RPF) preparing the THP)

E. Methods of Investigation

1. Reference all published and unpublished maps and reports.
2. List all aerial photographs and other imagery used in the study. Include copies of one set of stereo aerial photographs in the report with the THP boundaries outlined.

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3. List dates of field investigation/mapping.
4. Describe subsurface exploration methods (if done).
5. Include an analysis of the data (do not just give conclusions).
6. Describe applicable studies and technical models.

F. Individuals Contacted

II. Scope of Investigation

The scope of the engineering geologic investigation and report should be focused to evaluate the potential for proposed timber harvesting activities to adversely affect public health and safety, listed species or their habitat, water quality, or public lands. The scope of the report should be clearly stated and should be based on both the geologic constraints present at or near the site and the potential risk of those hazards on the environment. Where the report is focused on a single geology-related issue, an explanation of why the scope was limited should be included.

A. Public Safety
Has the RPF preparing the THP identified any houses, public buildings, roads or other features in a position where they could potentially be adversely affected by landsliding or surface soil erosion associated with the proposed timber harvesting activities?

B. Water Quality

1. Has the RPF identified that this THP has been in a watershed that has been classified as impaired by sediment by the U.S. Environmental Protection Agency or other regulatory agency?
2. Has the RPF identified any domestic water supplies that could potentially be impaired by sediment derived from timber harvesting activities? If so, these facilities should be shown on a map with respect to the proposed THP.

C. Listed Animal or Plant Species
Has the RPF identified listed rare, threatened or endangered species or their habitats within the watershed that could be adversely affected by potential landsliding or erosion associated with the proposed operations?

D. Public Lands
Has the RPF identified parks, wildlife refuges, or other public lands that could potentially be affected by landslides or soil erosion associated with the proposed timber harvesting activities?

III. Geologic Conditions

A. Bedrock Geology

1. Formation names and ages
2. Lithology (rock types)
3. Fabric (beds, joints, fractures) - The relationship of fabric and structural elements, where they are well defined and continuous, to hillslope aspects within or adjacent to the THP area should be evaluated.
4. General range in physical properties (density, hardness, strength, permeability) based on reconnaissance field work or data from other reports.

B. Seismotectonic Considerations
Provide concise information about the seismic and tectonic setting of the THP site and adjacent area and how it may relate to slope stability, surface soil erosion, or sedimentation.

C. Geomorphology

1. Landslides - Each landslide that could pose a significant risk to public health and safety, listed species or their environments, water quality, or public lands, and that may be adversely affected by proposed timber harvesting activities should be addressed in the engineering geologic report. The following information should be included:
   a. Description of type of landslide and its physical features (use nomenclature of Crudden and Varnes, 1996). Also see definitions for inner gorge, slide areas, unstable areas and unstable soils in the California Forest Practice Rules (see last page of this Note.)
   b. Documentation of landslide dimensions, including width, length, and depth and the method used to measure or estimate the dimensions.
   c. General description of type and density of vegetation and degree of revegetation in landslide area. If large trees are present in the landslide area, are any in a position where the landslide could potentially deliver woody debris to stream channels?
   d. Description of the ground slope(s) of the landslide and adjoining ground. Identify variations in slope greater than 10 percent along the landslide profile. Describe how slope measurements were made.

e. Describe the relative position of the landslide on the slope.

f. Evaluate the volume of sediment delivered to watercourses from landslides that have failed within the past 10 years.

1) Describe how sediment volumes were determined.

2) Estimate volume of sediment in a position to enter watercourses from each landslide, if any, and the relative rate of sediment delivery. Discuss the methods used to make the estimate.

g. Landslide materials (bedrock, weathered bedrock, soil, colluvium).

h. Degree of activity and/or relative stability - when was the landslide last active? Include discussion of reasoning used to determine activity and relative stability. Protocol for assessing relative stability should follow Keaton and DeGraff (1996).

i. Triggering mechanism - For historic landslides with known failure dates, did the landslide fail in response to a storm or earthquake event?

j. Slope modifications - did the landslide fail from a natural or modified slope? Have existing cuts and fills remained stable since the slopes were modified?

k. Identify springs, marshes, or wet areas.

l. Illustrations where needed, such as field-developed or interpretive cross sections, and detailed maps or illustrations of landslide features.

m. Provide other information as needed.

2. Landscape Geomorphology Indicative of Potentially Unstable Slopes

a. Inner Gorge - Refer to CGS Note 50.

b. Debris Slide Slope - CGS Note 50.

c. Other landforms, such as hummocky areas, closed depressions, disorganized drainages, disrupted linear features such as fences or roads, benches of questionable origin, tension cracks, leaning trees, or seepage sites.

d. Potential debris flow source area, such as colluvial filled swales inclined more steeply than 50 percent. Where computer models of steep topographic swales are available for a site from the landowner the RPF, or elsewhere, they should be included in the report.

D. Soil and Regolith from Published Soil Surveys or from the RPF as Modified by On-site Observations

1. Soil series

2. Soil thickness

3. Soil textural properties (grain size, plasticity, Uniform Soil Classification)

4. Soil drainage classification

5. Permeability contrasts between soil and underlying bedrock

6. Potential surface soil erosion hazard - identify how this was determined

E. Regional or local climate information as provided by the RPF. This should include, but not be limited to relative storm intensities, snow accumulations, and potential for rain-on-snow as it may affect terrain stability or surface soil erosion.

IV. Proposed Timber Harvesting Activities (obtained from THP)

A. Silviculture

B. Site Preparation

C. Yarding System(s)

D. Road and Landing Construction / Reconstruction and Maintenance

E. Winter or wet weather operations

F. Equipment operations on steep slopes

G. Other

V. Potential Effects on Slope Stability and Surface Soil Erosion from Proposed Operations

The engineering geologic report should provide a thorough, well-reasoned discussion or rationale and explicit conclusions on how the proposed timber harvesting operations may affect both short- and long- term site-specific slope stability and surface soil erosion. Potential effect-generating activities may include, but are not limited to road design and construction method, excavation and disposal of materials, road and skid trail drainage, road use and maintenance, vegetation removal, and site preparation.

VI. Cumulative Effects Assessment Related to Slope Stability, Surface Soil Erosion, and Sedimentation

A. Identify existing, ongoing problems associated with landsliding, surface soil erosion, and sedimentation within the THP area, including appurtenant and legacy roads. This will probably require interpreta-tion of historical aerial photo-graphy as well as office research, personal contacts, and fieldwork. Discuss how nearby geologically similar areas have responded to harvesting and road building in the context of significant storm events or earthquakes.

B. Discuss potential impacts from current or past activities within the watershed that could interact with potential effects from the proposed THP. These activities would include, but not be limited to, dams and water works, mining, other agriculture and grazing, urbanization, and roads.

C. From the context of geologic and geomorphic conditions and environmental concerns, evaluate how the proposed activities and any reasonably foreseeable future activities could interact with existing conditions within the watershed and how this may impact environmental issues of concern.

VII. Mitigation of Problem Areas

Identify areas of concern. Describe specific mitigative measures needed to minimize potential effects for the identified areas of concern. Where mitigations require an engineered design, the services of a civil engineer will be required. Mitigation monitoring plans developed in cooperation with the RPF should be included. The mitigations may be related to re-cent or dormant landslides, areas of surface soil erosion, new road construction, road reconstruction, stream crossings, yarding activities, silviculture, site preparation, cumulative effects within the watershed, and/or other factors. The mitigation work should be based on the potential hazard process (likelihood of landslide initiation or acceleration or an increase in surface soil erosion), the potential effects of the land-slide or increased erosion with respect to sediment mobilization or water flow, and the potential risk to public health and safety, listed species or their habitats, water quality, forest soil productivity, or public lands. The report should specify inspections and monitoring where needed.

VIII. References

All references used, including aerial photographs and other imagery, should be cited.

IX. Maps and Diagrams:

These should i nclude, but not be limited to the following:

A. Regional geologic and geomorphic map(s) at a scale of 1:24,000 or larger. This map should show the location of the THP and identify geologic features and downstream/ downslope resources that could affect or be affected by the proposed timber harvesting operations. This map should also provide regional information for the watershed in which the THP is being submitted to allow for an assessment of potential cumulative effects of sediment or debris identification. All maps should include a north arrow, bar scale, contour interval, and legend consistent with the guidelines defined by the BPELSG (2013).

B. Site location map, typically at a scale of 1:12,000. The scale of the site location map should be large enough to show all needed information. The map should display:

1. THP boundaries
2. Logging units
3. Road locations, characterized by width, drainage design, and surfacing; including existing, planned, and legacy roads (old and unmaintained roads)
4. Landing locations, including existing, planned, and legacy landings
5. Watercourses, springs, and wet areas
6. Silvicultural units
7. Landslides, gullies, or sediment depositional areas, including those not further discussed in the report.
8. Locations of analysis sites and mitigation points

C. Detailed site-specific maps and diagrams. Where specific information or mitigation measures are identified in the engineering geologic report, detailed maps, cross sections, diagrams, and/or schematic illustrations should be included at a scale that adequately presents the needed information.

X. Authority

The California Business and Professions Code requires that the PG, CEG, or GE must be working within his/her area of expertise and shall sign the final report. Inclusion of license numbers and/or official stamps shall be per the requirements of the licensing board.

REFERENCES

California Geological Survey Note 50, – similar to Note 52 Factors Affecting Landslides in Forested Terrain, January 2013, www.conservation.ca.gov/cgs/information/publications/cgs_notes/note-50

California Board for Professional Engineers, Land Surveyors, and Geologists, 2013, Geologists and Geophysicists Act (Business and Professions Code §§ 7800-7887, Chapter 12.5) with Rules and Regulations (California Code of Regulations, Title 16, Division 29, §§ 3000-3067) and Related Sections of the Business and Professions Code, Government Code, Penal Code and Evidence Code, January 1, 2013.

California Board for Professional Engineers, Land Surveyors, and Geologists, 2013, Professional Engineers Act (Business and Professions Code §§ 6700-6799, Chapter 7) with Rules and Regulations (California Code of Regulations, Title 16, Division 29, §§ 400-476) and Related Sections of the Business and Professions Code, Government Code, Penal Code and Evidence Code, January 1, 2013.

California Board for Professional Engineers, Land Surveyors, and Geologists, 1998, Guidelines for Engineering Geologic Reports, 8 p.

Crudden, D.M. and Varnes, D.J. 1996, Landslide Types and Processes *in* Turner, A.K. and Schuster, R.L., editors, Landslides: Investigation and Mitigation, Transportation Research Board, National Research Council Special Report 247, p. 36-75.

Keaton, J.R. and DeGraff, J.V., 1996, Surface Observation and Geologic Mapping *in* Turner, A.K. and Schuster, R.L., editors, Landslides: Investigation and Mitigation, Transportation Research Board, National Research Council Special Report 247, p. 178-230.

CALIFORNIA FOREST PRACTICE RULES - 2013

(Title 14, California Code of Regulations, Chapters 4, 4.5 and 10)

895.1.Definitions: Inner Gorge, Slide Areas, Unstable Areas, Unstable Soils

Inner Gorge means a geomorphic feature formed by coalescing scars originating from landsliding and erosional processes caused by active stream erosion. The feature is identified as that area beginning immediately adjacent to the stream channel below the first break in slope

Slide Areas are areas indicated by the following characteristics:

1. Shallow-seated Landslide. An area where surface material (unconsolidated rock, colluvium, and soil) has moved downslope along a relatively steep, shallow failure surface. The failure surface is generally greater than 65% in steepness and less than 5 feet in depth. It is usually characterized by: 1) a scarp at the top; 2) a concave scar below the scarp, where surface material has been removed; and sometimes 3) a convex area at the bottom where slide material is deposited. Vegetation is usually disturbed (tilted trees), anomalous (younger, evenaged stand), or absent (bare soil). Minor bank slumps are excluded from this definition.
2. Deep-seated Landslide. An area where landslide material has moved downslope either as a relatively cohesive mass (rotational slides and translational block slides) or as an irregular, hummocky mass (earthflow). The failure surface is generally deeper than five feet and is usually well-exposed at the head scarp. Complex failures with rotational movement at the head and translational movement or earthflows downslope are common. Vegetation on rotational and translational slides is relatively undisturbed, although trees and shrubs may be pistol-butted or tilted. Deep-seated landslides may have intermediate tension cracks, scarps, and shallow slides superimposed throughout the slide mass. Deep-seated landslide risk is usually associated with cohesive soils.

Unstable Areas are characterized by slide areas or unstable soils or by some or all of the following: hummocky topography consisting of rolling bumpy ground, frequent benches, and depressions; short irregular surface drainages begin and end on the slope; tension cracks and head wall scarps indicating slumping are visible; slopes are irregular and may be slightly concave in upper half and convex in lower half as a result of previous slope failure; there may be evidence of impaired ground water movement resulting in local zones of saturation within the soil mass which is indicated at the surface by sag ponds with standing water, springs, or patches of wet ground. Some or all of the following may be present: hydrophytic (wet site) vegetation prevalent; leaning, jackstrawed or split trees are common; pistol-butted trees with excessive sweep may occur in areas of hummocky topography (note: leaning and pistol-butted trees should be used as indicators of slope failure only in the presence of other indicators).

Unstable Soils may be indicated by the following characteristics:

1. Unconsolidated, non-cohesive soils (coarser textured than Loam , as defined in Appendix I.A.1a of Board of Forestry Technical Rule Addendum No. 1, dated December 15, 1981) and colluvial debris including sands and gravels, rock fragments, or weathered granitics. Such soils are usually associated with a risk of shallow-seated landslides on slopes of 65% or more, having non-cohesive soils less than 5 ft. deep in an area where precipitation exceeds 4 in. in 24 hours in a 5-year recurrence interval.
2. Soils that increase and decrease in volume as moisture content changes. During dry weather, these materials become hard and rock-like exhibiting a network of polygonal shrinkage cracks and a blocky structure resulting from desiccation. Some cracks may be greater than 5 feet in depth. These materials when wet are very sticky, dingy, shiny, and easily molded.

CALIFORNIA LICENSED FORESTERS ASSOCIATION
August, 1999

Guide To Determining the Need For Input From a Licensed Geologist During THP Preparation

Registered Professional Foresters (RPF) should address the following questions during Timber Harvesting Plan (THP) preparation. RPFs are encouraged to review California Division of Mines and Geology Note 50, *Factors Affecting Landslides in Forested Terrain*.

✓ Are there unstable areas located within or adjacent to the proposed THP area?

- Were unstable areas identified on available geologic, landslide, and watershed maps, aerial photos, or previous THPs in the vicinity of the plan area? [See Page 2 for instructions on how to obtain maps and other information]

- Were unstable areas observed in the field? Features associated with unstable areas may include:

  - Hillslopes greater than 65%, including inner gorge areas
  - Loose, unconsolidated soils
  - U-shaped swales
  - Irregular topography
    - Scarps
    - Benches
    - Hummocky ground
    - Surface cracks
  - Vegetative indicators
    - Leaning trees
    - Hydrophytes
    - Isolated patches of homogeneous vegetation
  - Disorganized drainage
    - Sag ponds
    - Seeps
    - Diverted watercourse
  - Road cut-bank failure
  - Road or landing fill failure

✓ If unstable areas were identified in the THP area, proposed timber operations on, adjacent to, upslope, or downslope of these features may have the potential to affect slope stability through:

- Displacement of soil,
- Division or concentration of drainage,
- Reduction in interception or transpiration, and/or
- Reduction in root strength.

Examples of timber operations that may produce these effects are:

- Timber cutting
- Construction and maintenance of:
  - Roads
  - Stream Crossings
  - Skid trails
  - Beds for felling of trees (layouts)
  - Fire breaks
- Mechanical site preparation
- Prescribed burning

✓ If proposed timber operations have a reasonable potential to affect slope stability, and there is a potential for materials from landslides or unstable areas to affect public safety, water quality, fish habitat or other environmental resources, then a California licensed geologist with experience/expertise in slope stability should be consulted to assess slope stability and assist with designing mitigation measures**.**

A series of 7.5' quadrangle landslide maps has been developed for use in THP preparation that covers much of the California Coast Range, from Monterey through Del Norte Counties. An index for these maps, California Division of Mines and Geology Special Publication 120, is available from:

Division of Mines & Geology
Publications and Information Office
801 K Street, MS 14-33
Sacramento, CA 95814-3532
916-445-5716

Copies of the landslide maps are on file at the Division of Mines and Geology library at the above address and at the Department of Forestry and Fire Protection offices in Fortuna, Willits, Santa Rosa, and Felton.

Many of the maps that are published by the Division of Mines and Geology are available at:

www.consrv.ca.gov/dmg/index.htm