FORESTRY, LANDSLIDES AND PUBLIC SAFETY

An Issue Paper prepared for the
Oregon Board of Forestry

By the Landslides and Public Safety
Project Team

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Executive Summary

Severe winter storms impacted Oregon in 1996. These storms produced record rainfall and triggered landslides in many parts of the state. Some of these landslides became dangerous debris flows or debris torrents (landslides that move rapidly down stream channels). Two debris torrents killed five people during the November storm in southwest Oregon. These fatalities were associated with landslides that initiated within recent forest operation areas (clearcuts less than 10 years old).

Prior to 1997, the Oregon Forest Practices Act (FPA) contained no public safety responsibility or authority. Since then, many steps have been taken to better protect Oregonians from these hazards, including:

- Implementation of the Governor's Debris Avalanche Action Plan;
- Passage of Senate Bill 1211 with its interim prohibition of forest operations on steep slopes above homes and busy roads;
- Passage of Senate Bill 12 (legislation requiring shared responsibility for rapidly moving landslides);
- Publishing of the ODF "Storm Impacts and Landslides of 1996" Monitoring Study.

Senate Bill 12, which passed in 1999, found that "rapidly moving landslides present the greatest risk to human life, and persons living in, or traveling through, areas prone to rapidly moving landslides are at increased risk of serious bodily injury or death." The Board of Forestry (Board) is required to adopt rules to replace the interim prohibition of operations authorized by Senate Bill 1211 (1997) and extended by Senate Bill 12 (1999). These rules must consider the exposure of the public to these safety risks and shall include appropriate practices designed to reduce the occurrence, timing, or effects of rapidly moving landslides. These new laws may now expose the Board and Department of Forestry (department) to increased legal liability after future landslide-related impacts if the provisions of the Senate Bill 12 are not followed or if there is negligence.

The Board adopted six guiding principles for this project in April 2000. These guiding principles recognize that protection of the public from rapidly moving landslides is a shared responsibility, and that forest practices regulations should be risk-based. A diverse project team was assembled to consider this issue, review scientific information, and assist the department in making recommendations to the Board. Project Team members and additional technical experts have reviewed the issue paper, and it has been edited accordingly.

This issue paper describes:

- Scientific information on the causes and behavior of rapidly moving landslides;
- Hazards and risks associated with these landslides;
- Methods used to identify locations prone to rapidly moving landslides;
- Forest practices that are intended to reduce risk to people;

- Consideration of policies that are intended to reduce risk to people;
- General strategies and specific alternatives; and
- Recommendations of the Project Team.

Science

Landslides are a dominant erosion process on steep, forested slopes in western Oregon. There are many factors that affect landslide susceptibility. Subsurface water and associated pore-water pressure within the soil are the most important factors associated with the occurrence of most landslides. In the natural setting, these factors interact in complex manners and, except for slope steepness, important parameters like the shape of the ground under the soil (bedrock surface), groundwater distribution, and rock fractures are usually difficult or impossible to determine reliably. It is not possible to predict when any specific location will experience a rapidly moving landslide, but it is possible to recognize locations where these landslides are more likely.

Vegetation removal often has a negative effect on the stability of steep slopes. In the Oregon Department of Forestry (ODF) storm impacts study, higher landslide densities were found in stands that had been harvested in the previous nine years (as compared to forests older than 100 years), at least in three out of four study areas. Forested areas between the ages of 30 and 100 years typically had lower landslide densities than mature forest stands (over 100 years old). The storm impacts study was not designed to explain these differences in landslide densities. Average landslide volume was similar regardless of the age of the forest stand.

These differences in landslide occurrence by forest stand age are most likely due to differences in root reinforcement and/or changes related to the forest canopy. Most existing research on the effects of forest removal on slope stability has focused on root strength. There is little or no applied research on the effects that vegetation removal has on hillslope hydrology, although research does show that the loss of forest canopy increases pore-water pressure in soils (thus reducing slope stability).

Roads can clearly increase landslide hazard by making slopes steeper and directing drainage to steep locations. Road-associated landslides are usually larger than landslides associated only with vegetation removal.

Small landslides can become large, rapidly moving debris flows and, when they enter stream channels, debris torrents. However, large initial landslides are more likely to result in large debris torrents. Most landslides do not become rapidly moving debris torrents. Conditions over the landslide path probably have the greatest influence on debris flow and torrent potential. Conditions at the initiating landslide probably have a lesser influence on this potential. Confined channels in steep, dissected terrain that contain a lot of debris are most susceptible to debris torrents. Debris torrents are the major public safety issue.

Hazard and Risk

Hazard refers to the inherent susceptibility of a given location to some event that could produce negative consequences (for example, the likelihood that a landslide or debris torrent will occur). Risk is the likely consequence associated with the occurrence of a hazard negatively impacting a valued resource. Landslides can occur without having a significant effect on any resource. When landslides become debris flows/torrents, they can have both negative and positive effects on fish habitat. However, if people are exposed along their path, debris flows and torrents can only have negative effects and pose a risk to these people.

The factors that increase or decrease the risk from rapidly moving landslides include the:

- Recurrence frequency of debris flows/torrents in the affected location;
- Velocity, size, and composition of the debris flow/torrent at the location of the population;
- Time people spend in these dangerous locations;
- Protection afforded by buildings or vehicles;
- Land management practices that may reduce stability at the site of the initiating landslide or increase the size of the debris flow/torrent.

Rapidly moving landslides are part of the natural geologic process. Channels where rapidly moving landslides have occurred in the past will experience these landslides again in the future. Even in an extreme storm event, only a small percentage of the landslide-prone locations will fail, but these landslides may affect a fairly large portion of the stream channel network. Although the current forest practices rules use only one category (high) for evaluation of hazard (and risk), there is, in reality, a gradation of hazards on the landscape. Similarly, there is also a gradation of risk.

Identification of Landslide-Prone Locations

The current forest practice rules define “high risk areas” and “high risk sites" to identify landslide-prone locations. Locations that are subject to debris flow/torrent impacts are best understood as pathways, and not as single location(s). Maps can be developed to help identify areas prone to landslides and their impact locations. The department has mapped debris flow hazard in western Oregon. However, they are low-resolution maps, and thus do not accurately show areas at risk of rapidly moving landslide impacts. The Department of Geology and Mineral Industries (DOGAMI) is currently mapping "further review areas" (locations prone to rapidly moving landslides). The DOGAMI maps should provide the most consistent map information on landslide initiation locations, debris flow paths, and other locations at risk from rapidly moving landslides.

Ground-based investigation provides the most reliable information on landslide-prone locations. The department's current criteria for identification of locations prone to initiation of rapidly moving landslides uses slope steepness and the shape of the ground surface. These criteria identified between 80 to 90 percent of the landslides found in the ODF storm impacts study.

Forest Management Practices

Because of geologic processes, sites prone to shallow-rapid landslides are subject to these landslides, regardless of forest management. Management can increase this natural hazard. There is generally an increased landslide hazard on very steep slopes for a limited period of time after timber harvesting. Research on the efficacy of alternative silvicultural (partial cutting, for example) or logging practices does not exist. A Silviculture and Landslides Susceptibility Report (Appendix 3) addresses this issue using literature describing forest root and canopy loss and growth. Leave-areas of sufficient size to provide roots, canopy cover, and to prevent increased blow-down are perceived to provide the greatest protection against timber harvest-related slope instability. Silvicultural practices that reduce the land area in a condition with reduced roots and forest canopy or that reduce the amount of time landslide-prone sites have reduced roots and canopy should result in an intermediate landslide hazard.

Forest roads can increase landslide hazard to a greater extent than timber harvest. Woody debris in the path of a rapidly moving landslide may further increase the severity of a dangerous debris torrent. Practices that reduce or eliminate woody debris loading in channels may reduce the size and/or travel distance of debris torrents.

Policy Considerations

To help the Project Team focus on the key issues, seven policy considerations were identified, reviewed, and discussed by the team.

1. It is important to consider hazard and risk separately for identification of locations prone to initiation or impact from rapidly moving landslides.
2. Using the same general site identification criteria for public safety as for natural resources should reduce rule complexity and allow more consistent rule application.
3. Developing rule concepts that are scaled by risk is required by law and the guiding principles.
4. Evaluating different silvicultural alternatives is one means to develop practices that are scaled by risk.
5. Practices that reduce debris loading in stream channels that are prone to debris torrents and that are above homes or roads may reduce debris torrent impacts.
6. Completed structural mitigation projects (in the channel or around the home) should be considered in determination of necessary forest practices regulations, since they can, in some cases, more efficiently provide public protection.
7. It is important to include in the rules objectives a statement to the effect that landslides will continue to occur despite any forest practices regulations.

Strategies and Alternatives

Forest practice regulations can be one element of a strategy to protect Oregonians from rapidly moving landslides. Forest management activities may affect the timing and the magnitude of rapidly moving landslides. By themselves, however, forest practice regulations do nothing to affect the inherent (geologic) hazards associated with rapidly moving landslides. Therefore, if forest practices regulations are to be effective, they must be incorporated with strategies to reduce the population in hazardous locations during major storm periods. A number of strategies have been developed by the department with Project Team input to help address the landslides and public safety issue, as described below:

Four Strategies

I. Developing risk-based forest practices regulations. This strategy includes the following sub-strategies:
A) Screening of operations that may have landslides/public safety effects.
B) On-the-ground identification of high hazard landslide-prone (initiation) locations within proposed operations.
C) Evaluating rapidly moving landslide hazard for screened operations.
D) Requiring forest practices that maintain and/or rapidly recover root strength and canopy and that reduce or prevent road-associated landslides on high (landslide initiation) hazard locations with high public safety risk downslope.
E) Using debris flow path management practices that reduce debris loading and/or reduce debris flow travel distance.

II. Improving residents' ability to recognize where and when they might be at risk from rapidly moving landslides and how they can protect themselves.

III. Providing physical mitigation between high hazard sites, homes, or roads.

IV. Reducing the number of dwellings, and during extreme rainfall periods, vehicles in locations prone to rapidly moving landslide impact, since regardless of management, there is high hazard in these locations. This strategy is designed to reduce the conflicts between forest management and persons in vulnerable locations.

A number of alternatives were developed for each strategy and sub-strategy. An assessment of costs, benefits and scientific uncertainty was also considered during the evaluation of alternatives and are found in the issue paper.

Recommendations

The Project Team modified and combined alternatives as it deemed technically appropriate and in order to develop team consensus. Unless otherwise stated, the team agreed to all recommendations by consensus.

Strategy I. The Project Team recommends that the Board consider three exposure categories to assess risk and to determine the appropriate forest practices. These three categories, based on the likelihood of people being present during dangerous periods, are:

Exposure Category a. Habitable residences, schools, commercial or public offices. (Structures that are frequently - 25% or more of the time - occupied during the storm season - November 1 through April 30).
Exposure Category b. Roads with over 500 vehicles per day.
Exposure Category c. Barns, outbuildings, recreational dwellings, low-use public roads (Structures and roads where people are not usually present).

The Project Team also determined that setting the level of appropriate risk is a policy decision for the Board of Forestry, and not a technical decision for the Project Team. Based on the Exposure Category and hazard level, the appropriate forest practices can include no roads or harvesting for the highest risk, special silvicultural practices for intermediate risk, and natural resource protection practices for low public safety risk. Information on relative risk from rapidly moving landslides (pages 40 through 47 in the issue paper) should be considered in determining the level of appropriate risk for these different forest practices levels. During their discussions, the Board should consider residences differently from highways, since it is possible to control traffic on highways (and thus keep people away from the hazard). Also, there may be instances where hazard is so extreme that it is appropriate to raise the protection level.

Sub-strategy 1.A. The Project Team recommends that Further Review Area Maps be used to identify locations prone to rapidly moving landslides (alternative I.A.1-3). The Department of Geology and Mineral Industries is currently developing these maps as directed by Senate Bill 12, and plans to have them complete in the spring of 2002. The Project Team also recommends that these maps be updated as new information becomes available.

The Project Team recommends that operators should be required to identify structures and roads within mapped further review areas below any operation that also contains further review areas within the operation area (I.A.2-3). The department should notify operators that their operation contains further review area(s), and the department should also share responsibility to find homes and, where appropriate, roads by independently checking these locations (alternative I.A.2-2). Finally, as a longer-term project, the Project Team recommends that the department investigate developing a map or other inventory tool (alternative I.A.2-1) that accurately identifies the locations of homes and highways and busy roads (such a map currently does not exist).

Sub-strategy 1.B. The Project Team recommends that the Board adopt into rule form the current high risk site criteria used by the department (alternative I.B.1). This was also a consensus recommendation of the Forest Practices Advisory Committee (FPAC). These locations would be identified as "high hazard locations" not "high risk sites," since risk depends on conditions along the debris flow/torrent path. Oregon Department of Forestry (ODF) will screen and notify landowners about high hazard locations.

Sub-strategy 1.C. The Project Team recommends that the department evaluate rapidly moving landslide hazard using information from the debris flow impacts study (alternative 1.C.1), as described in Appendix 4. Hazard would be based on the physical conditions in the debris flow shed, and on the specific location of the vulnerable population. As more information becomes available, these criteria should be modified as appropriate. The department should use debris flow runout models (alternative I.C.2) to help validate these hazard evaluation methods. Finally, if a landowner so chooses, a geoscience professional should be used to collect specific physical information in the field to better assess hazard (alternative I.C.3). The department should let landowners know when the use of a geoscientist is prudent, and should review all geoscientist-provided information to ensure it is based on field-specific physical information.

Sub-strategy 1.D. The Project Team recommends that the Board adopt rules that do not allow any reduction in root strength or canopy cover in the **highest risk situations** (alternative 1.D.1). This would allow no harvesting, except to remove dead trees, to prevent loss of other vegetation by disease, or to remove trees from sites that have already failed and, in these cases, only where the operator can demonstrate that the operation results in no increased landslide hazard. Department geotechnical specialists would make the final determination whether the operation increases landslide risk. The Project Team also recommends that the Board adopt rules that do not allow road construction in the highest hazard locations (alternative I.D.2). In limited cases, road reconstruction should be allowed if the operator can show that this results in a reduced landslide hazard.

The Project Team recommends that the Board adopt rules that describe silvicultural practices to limit the increase in landslide hazard associated with vegetation removal for **intermediate risk situations** (alternative 1.D.3). These silvicultural practices include limits on the acreage in vulnerable condition by landowner or operation. The team also recommends that practices to ensure more rapid canopy and root recovery be developed into rule form (alternative 1.D.4) and similar practices to ensure less loss of canopy and roots (for thinning) also be developed (alternative 1.D.5).

The Project Team recommends that roads constructed on high hazard locations and with **intermediate downslope public safety risk** follow site specific recommendations of a geotechnical specialist to ensure drainage is not diverted to any high hazard location (alternative 1.D.6). The Project Team also recommends that forest road construction operations that might result in large, rapidly moving landslides be subject to special public safety review (alternative 1.D.6). Fills in narrow canyons and waste disposal areas are currently only reviewed for natural resource protection purposes.

Sub-strategy 1.E. The Project Team recommends that the Board adopt rules that require operators to fall and yard trees to minimize slash and other debris accumulations in channels above homes and roads (alternative 1.E.1). Operators should be required to remove accumulations of slash that enter these channels (alternative 1.E.2). The Project Team also recommends leaving larger trees standing next to the lower (6 to something under 20 percent) gradient part of debris torrent-prone channels (alternative 1.E.3), since there is limited evidence that trees in these locations may reduce debris torrent travel distance. The Project Team also recommends that the Board discuss the policy implications of the differences between debris management for fish as compared to public safety (since wood is beneficial for fish habitat, but is likely to increase public safety dangers associated with rapidly moving landslides).

Strategy II. The Project Team recommends that the department work with other appropriate agencies and technical experts to develop information for persons living in locations prone to rapidly moving landslides (alternative II.1). The team also recommends that the department work with local governments to provide this information to these residents (alternative II.2). The team also strongly recommends that the Governor's Interagency Hazard Mitigation Team, with the assistance of Oregon State University, lead an effort to obtain additional radar site and real-time rain gages so that the current warning debris flow warning system is significantly improved (alternative II.3). This alternative will also improve flood forecasting and warnings in the Coast Range.

Strategy III. The Project Team recommends that mitigation (actions to control or re-direct rapidly moving landslides) should generally use structural measures that are designed by a licensed professional (alternative III.1). This will be the responsibility of forest landowners with input from affected homeowners and not the responsibility of State or local government. The Project Team also recommends that rules be drafted to specifically allow landowners to remove trees on locations where the public safety risk from trees blowing over on specific sites is higher than from rapidly moving landslides initiating on those same sites (alternative III.2).

The Project Team believes that homeowners' management of landslide-prone forestland above their homes (alternative III.4) is a policy consideration for the Board. Specifically, are there situations where, despite the landslide hazard, a homeowner may conduct forest practices on landslide-prone terrain above their own home? The Board should consider potential impacts for persons who were not party to these decisions (renters, children, and potential home-buyers).

Strategy IV. The Project Team recommends that the Board of Forestry develop a formal policy to encourage voluntary agreements between forest landowners and homeowners to remove or relocate structures in locations prone to rapidly moving landslides (alternative IV.1). This policy should then be effectively communicated to the affected parties. The Office of Emergency Management should effectively encourage local governments to acquire properties hit and damaged or destroyed by rapidly moving landslides (alternative IV.2). Since local governments may not want to keep these properties because of liability concerns, Board management, instead of local government management, of these properties could encourage more local governments to make these acquisitions. The Project Team also recommends that the Board develop a joint policy with the Land Conservation and Development Commission stating that development of new homes in locations prone to rapidly moving landslides is not compatible with forestry uses (alternative IV.4).

The Project Team recommends that the Department of Transportation work with the Department of Forestry, Department of Geology and Mineral Industries, and the Office of Emergency Management to develop road management procedures for highways prone to rapidly moving landslides (alternative IV.3). These procedures should better inform motorists of rapidly moving landslides and greatly reduce the likelihood of vehicles being stopped in locations prone to rapidly moving landslide impacts on the most critical highways. The department should report back to the Board on the results of this collaborative effort.

The Project Team recommends that the department develop three different guidance documents for:

- Geoscience investigations of proposed dwelling locations (alternative IV.5);
- Local governments' review of these investigations, describing the standard elements of geoscience reports (alternative IV.6); and
- Procedures for ODF review of home sites in further review areas (alternative IV.7).

The Project Team **strongly** recommends that the Board work with local governments and the legislature to change the provisions of Senate Bill 12 that currently do not allow local governments to prohibit new home construction in dangerous locations prone to rapidly moving landslides (alternative IV.9).

The Project Team recommends that the Office of Emergency Management and the Department of Land Conservation Development work together to investigate options for developing an insurance program based on the Further Review Area Maps currently being developed and on the authorization to include mudflow-prone areas in the flood insurance program.

Finally, a majority of Project Team members recommend that the Board develop possible strategies for landowner compensation, since in some cases, landowners may be precluded from harvesting a substantial portion of their property.

I. PURPOSE

This issue paper provides necessary information for the Board of Forestry (Board) to develop regulations as per Senate Bill 12 (1999), dealing with protection of public safety associated with rapidly moving landslides that might begin on forestlands. This issue paper also includes strategies, policies and non-regulatory actions designed to help the Board and Department of Forestry (department) reduce the inherent conflicts between persons in dangerous locations and forest management actions on steep slopes.

II. ISSUES

There are a number of issues that need to be addressed during this project, as described below.

1. How can forest practices regulations reduce the risk of serious bodily injury from rapidly moving landslides that originate on forestlands?

2. How can the Board develop rules to meet the statutory requirements of Senate Bill 12?

3. How can the Board develop rules to meet the statutory requirements of ORS 527-714 [Findings and analysis required prior to rule adoption]?

4. How should "substantial" risk of serious bodily injury be defined.

5. What can the Board do to make public safety regulations and other actions consistent with the Forestry Program for Oregon and with existing Forest Practice rules for natural resource protection?

6. What can the Board do to ensure its actions compliment other State and local programs dealing with landslide risks?

7. What can be done to help all affected parties appropriately share responsibility to reduce risks associated with rapidly moving landslides?

8. What locations should be subject to special regulations for public safety?

9. How should the Board make decisions with limited scientific information, or where scientific uncertainty is significant?

III. BACKGROUND

Storms of 1996

Two major landslide producing winter storms occurred in Oregon during the calendar year 1996. The February storm resulted in widespread landslide occurrence and associated impacts to natural resources. In response to these impacts, the Oregon Department of Forestry (department) began its "Storms of 1996" monitoring study. Then, in November, a second extreme storm triggered many more landslides. Two of the November landslides, both of which began within recently logged areas, resulted in five fatalities. In early 1997, the Board considered actions to reduce the potential for landslide-related injuries associated with forest management practices. At the same time, Governor Kitzhaber issued a "Debris Avalanche Action Plan."

Existing Regulations

The primary legal authority for the Department of Forestry relating to landslides and debris flows is found within the Oregon Forest Practices Act (FPA) (ORS 527.610 to 527.992). Prior to 1997, the FPA contained no public safety responsibility or authority. Therefore, the Board's recommendations and the Governor's action plan both called for a voluntary deferral of timber harvesting on high risk sites above homes and highways. After reports of a few operators ignoring the voluntary deferral, the Board recommended legislation to put a temporary deferral into law. Senate Bill 1211 (1997) was the law which resulted.

Forest practices definitions and rules

The Board adopted most of the current landslide prevention rules in June 1983. Rules for harvesting on high risk sites were adopted in 1985. The forest practice rules for harvest operations are intended to minimize both surface and mass (landslide) erosion. Harvest practices are subject to added regulation if they affect high risk sites.

OAR 629-600-100 - Definitions

(27) "High risk areas" are lands determined by the State Forester to have a significant potential for destructive mass soil movement or stream damage because of topography, geology, biology, soils, or intensive rainfall periods.

(28) "High risk sites" are specific locations determined by the State Forester within high risk areas. A high risk site may include, but is not limited to: slopes greater than 65 percent, steep headwalls, highly dissected land formations, areas exhibiting frequent, high-intensity rainfall periods, faulting, slumps, slides, or debris avalanches.

OAR 629-630-500 Harvesting on high risk sites in western Oregon

(1) In the Northwest Oregon and Southwest Oregon regions, operators shall obtain prior approval from the State Forester before conducting harvesting operations on high risk sites.

(2) Written plans, where required for harvesting on high risk sites, will describe how harvesting operations will be conducted to minimize impact upon soil and water resources.

Standard practices (generally defined in the administrative rules) for the protection of high risk sites during forest harvesting and stand management activities on private lands in Oregon include:

- Felling timber to minimize ground disturbance and slash accumulations on high risk sites;
- Not building skid trails on high risk sites;
- When yarding across high risk sites, providing at least one end suspension and ensuring that logs do not gouge soils;
- Not building landings on high risk sites, and avoiding placement of landing debris or landing drainage on high risk sites; and
- Replanting as soon as possible after logging.

The following additional practices have been used to protect high risk sites on private and state lands in Oregon, but are not considered standard practices or requirements in most cases, at least where public safety is not in question.

- Leaving non-merchantable trees and understory vegetation relatively undisturbed;
- Avoiding prescribed burning;
- Avoiding use of herbicides;
- Leaving a buffer area around headwalls (headwall leave-areas);
- Thinning the stand instead of clearcut harvesting; and
- Not harvesting the area.

Senate Bill 1211 (1997)

Senate Bill 1211 applied an interim prohibition of operations to sites meeting all three of the following conditions:

1. High risk sites exist within an area proposed for a road construction or timber harvesting operation;
2. Precariously sited, inhabited buildings or high traffic volume county roads (at least two lane and paved) or state highways are below the operation area and are in the potential path of a landslide, debris flow, or torrent that could originate on a high risk site in the operation area; and
3. The precariously sited inhabited buildings or high traffic volume county roads (at least two lane and paved) or state highways are located such that a landslide or debris torrent originating in the operation area would be moving with such force that it would be a significant threat to persons occupying houses or vehicles.

Task Force on Landslides and Public Safety

Senate Bill 1211 also called for formation of a “Task Force on Landslides and Public Safety.” This Task Force included a member of the Board of Forestry (Wayne Krieger). In working with the interim task force, the department explained that landslides in Oregon are not limited to forestlands and need to be addressed across all landscapes where public safety and other considerations are at risk. The Task Force also heard that the best available scientific information indicates that timber harvesting is associated with higher landslide occurrence on very steeply sloped forestlands for a period of about ten years after the harvest, and that landslide occurrence was lowest in stands between 30 and 100 years old. The Task Force was also informed by the department that it is not possible, even with a strict prohibition of all timber harvesting on steep slopes, to prevent all or even a majority of landslides.

Senate Bill 12

The Task Force made a series of recommendations, including the legislative concept that was a precursor to Senate Bill 12 (1999). The department testified that Senate Bill 12 equitably addresses landslide issues across all affected parties. Therefore, the department supported passage of Senate Bill 12, since it clarifies the public safety responsibilities of other state and local government agencies beyond what can be accomplished through the regulation of forest management practices. Senate Bill 12 recognizes that the most certain way to avoid public safety threats from dangerous landslides is to keep people out of precarious locations, especially during extreme rainfall periods. Senate Bill 12 requires the Board of Forestry to adopt rules that reduce the public safety risk from rapidly moving landslides directly related to forest management practices. Applicable language from Senate Bill 12 can be found in Section IV of this issue paper, and the full text is found in Appendix 1.

Administration of the Interim Prohibition of Operations

As of April 2001, the department has been notified of 88 operations meeting interim prohibition characteristics on all or a portion of these operations. The interim prohibition has completely precluded harvesting two of these operations. Eighty-one operations have been subject to leaving a portion of the proposed operations unharvested. Total land area excluded from harvest was 786 acres. Finally, five operations have been granted deferral exceptions because the danger of windthrow to a nearby residence was greater than the landslide risk at those sites. The department has advised landowners to obtain the services of geotechnical professionals (engineering geologists or geotechnical engineers) for operations where a portion of the proposed logging unit was subject to the interim prohibition of operations.

Note that most landowners have screened their lands using the department's guidance and are not presently proposing forest operations in these areas. Therefore, the actual number of operations affected by the interim prohibition is significantly greater than 88. As required by Senate Bill 12, administration of the interim prohibition of operations on certain high risk sites will continue until rules are adopted by the Board of Forestry and then promulgated.

Implementation of the Governor's Debris Avalanche Action Plan

After meeting with the directors of several agencies, Governor Kitzhaber and his staff developed a plan to address rapidly moving landslides. This plan was issued on March 4, 1997, just prior to the Board of Forestry meeting where landslide and public safety issues were presented. The plan sets forth specific recommendations and actions to be taken by the state and local governments to reduce the occurrence of these slides and reduce the risk to the public when these slides do occur. The Governor's recommendations are listed first, followed by the actions completed to date (*in italics*).

Oregon Department of Forestry (ODF) actions

1. Recommend that the Board of Forestry require written plans for all harvest and road building activities on high risk sites. Written plans would delineate measures to be used to mitigate the risk of debris flows. Ensure that financial resources are available for identification of high risk sites.

Actions to date: The Board of Forestry directed the department to revise rule guidance for operations on high risk sites. Written plans are now required by policy for all harvesting and road construction operations on high risk sites (not just public safety sites). Guidance for identification of high risk sites was made clear and very specific. The screening process used to identify high risk sites does not take a great deal of resources. If forest practices foresters cannot conduct a site visit, operators can be required to use ODF guidance and find high risk sites.

2. Recommend that the Board of Forestry require notice to landowners downslope and within a certain distance of harvest or road building operations on high risk sites.

Actions to date: Prior to the effective date of Senate Bill 1211, ODF notified all homeowners below and close to operations on high risk sites. Since these operations are now prohibited, *notification is only necessary for those infrequent cases where exceptions to the deferral are approved (i.e., high blow-down hazard above house or road). In addition, when ODF personnel find evidence of extreme landslide hazards, whether or not in a recent operation area, homeowners are notified. This has, at times, resulted in severe distress to the homeowner.*

3. Defer clearcuts and road building in areas with a high risk of debris flows that threaten human lives until appropriate statutory and administrative changes have been made.

Actions to date: Since Senate Bill 1211 became effective, the department has not approved written plans on sites meeting the public safety criteria.

Oregon Department of Transportation (ODOT) actions

1. Assess state highways for public safety hazards from debris avalanches and mudflows.

Actions to date: The Department of Transportation routinely evaluates the stability of existing landslide areas within the highway right-of-way.

2. Coordinate with the Oregon Department of Forestry when timber harvest or road construction is planned above and within a certain distance of a state highway. The system will provide for timely input and recommendations from ODOT to ODF regarding forest road building and timber harvest.

Actions to date: Prior to the effective date of Senate Bill 1211, ODOT and the department developed a system to communicate information about operations on high risk sites above state highways. With the interim prohibition in effect, this is no longer necessary.

3. Increase road patrols during heavy precipitation periods.

Actions to date: ODOT has increased road patrols on portions of Oregon Highways 6 and 38, and Interstate Highway 84 during periods of heavy rain. Resources are available for 24-hour patrols when necessary.

Oregon Building Codes Division action

Adopt appropriate portions of the uniform building code and examine ways in which structural, drainage, and landscaping codes could be modified to reduce risk from landslides and to reduce factors that may contribute to landslides in developed areas. Appropriate focus should be on foundation standards, slope stabilization, and diversion barriers.

Action to date: Changes related to foundation standards and slope setbacks were made in early 1996, prior to this action plan. No major changes related to landslides have been made since.

Oregon Department of Land Conservation and Development (DLCD) actions

1. Review Goal 7 to determine whether it effectively addresses landslides and other natural hazards.

Actions to date: DLCD reviewed its Statewide Planning Goal 7 (natural hazards). This review includes all major hazards (landslides, flooding, wildfire, earthquakes, tsunamis-coastal, etc.). The review evaluates the effectiveness of Goal 7, including possible actions to make Goal 7 more effective, and recommends specific measures to improve its implementation. DLCD has also produced Technical Resource Guides to help local governments deal with natural hazards. The department provided much input into the landslides technical resource guide. A hearing on recommended Goal 7 language is scheduled for July 2001.

2. Develop and distribute model local land-use regulations that would restrict development in canyons and on debris avalanche fans.

Actions to date: The Department of Land Conservation and Development awarded a grant to Douglas County for development of a model ordinance. Douglas County staff developed a model ordinance that is consistent with the requirements of Senate Bill 12. Note that Senate Bill 12 now prevents local governments from restricting development in these most dangerous locations in many cases.

Oregon State Police - Office of Emergency Management (OEM) actions

1. Make the Governor's Interagency Hazard Mitigation Team (G-IHMT) a permanent body. Direct the team to establish regular meeting dates and revisit its recommendations relating to landslides.

Actions to date: OEM convenes the G-IHMT on a regular basis.

2. Recommend that local governments prepare debris avalanche action plans using the state hazard mitigation plan as a guide. The state will help identify federal funding for counties to help pay for this work. Encourage coordination with the Oregon Department of Geology and Mineral Industries (DOGAMI) for assessing geologic hazards.

Actions to date: OEM has promulgated a natural hazards mitigation plan for Oregon. OEM staff worked closely with ODF, DLCD, and DOGAMI staff to develop the landslide chapter of this mitigation plan.

3. During intense storm events, act as lead agency in coordinating among appropriate state agencies on risk from landslides in both rural and urban areas.

Actions to date: OEM's role as the state agency responsible for coordinating and facilitating management of state resources in the event of a natural disaster is established by statute and implemented through the Oregon Emergency Response System.

4. Coordinate with DOGAMI and the National Weather Service on an improved warning system. Consolidate weather, hazard, and situation information and make it accessible by all agencies in a timely manner.

Actions to date: ODF has taken the lead on this item. ODF geotechnical specialists developed the warning system criteria. ODF meteorologists do the storm forecasting. Advisories or warnings are issued based on threshold precipitation criteria and by consultation with geotechnical specialists. Warnings are transmitted to the National Weather Service and to OEM, who in turn disseminate the information. DOGAMI provides technical information in response to media or public questions. Implementation of the debris flow warning system will continue, typically on a seasonal basis between October and April.

Oregon State University and ODF combined action

Undertake hazard mapping designed to inform local governments, landowners, and homeowners of the presence of factors that may contribute to debris flow avalanches. Among these could be precipitation, lithology, landform, land-use classification, and slope.

Actions to date: The department took the lead on this project, after State Climatologist, George Taylor, completed mapping of short-term rainfall intensity for western Oregon. Maps have been completed for all of western Oregon and have been placed on the department's web site. These maps show the relative potential for impact by debris flows (rapidly moving landslides) at a coarse scale. DOGAMI is currently mapping further review areas (more detailed and precise maps) as per the requirements of Senate Bill 12.

Department of Geology and Mineral Industries action

Develop a coordinated public education campaign. Ensure that financial resources are available for an effective campaign.

Actions to date: DOGAMI developed a landslide public outreach brochure in cooperation with the department and several other state agencies. DOGAMI made a special effort to distribute the brochure in southern Oregon. DOGAMI is also the lead media contact for the debris flow warning system.

Governor’s Office actions

1. Support legislation requiring full disclosure of known landslide history and available information on risk during all property transactions.

Actions to date: The Governor's Office helped to develop and actively supported passage of both Senate Bills (1211 and 12) that passed through the legislature, and also supported Senate Bill 13 (disclosure) which did not pass. Provisions for recording geotechnical reports, were, however, added to Senate Bill 12 in Section 4(1)(d).

2. Support a thorough discussion of ways to lessen the inherent conflict between resource use of steep hazardous ground and residential or other developed uses.

Actions to date: The Governor's Office supported both Senate Bill 1211 and Senate Bill 12 including the shared responsibility concept which is now part of Oregon's policy for rapidly moving landslides.

IV. STATUTORY REQUIREMENTS

Senate Bill 12

SECTION 3. The Legislative Assembly finds that:

(1) Many locations in Oregon are subject to naturally occurring landslide hazards, and some human activities may accelerate the incidence or increase the adverse effects of those hazards.

(2) Rapidly moving landslides present the greatest risk to human life, and persons living in or traveling through areas prone to rapidly moving landslides are at increased risk of serious bodily injury or death.

(3) Although some risk from rapidly moving landslides can be mitigated through proper siting and construction techniques, sites that are vulnerable to impact from rapidly moving landslides are generally unsuitable for permanent habitation.

(4) Activities that require sound decisions to mitigate rapidly moving landslide hazards and risks include, but are not limited to:

(a) Siting or constructing homes or other structures in areas prone to rapidly moving landslides;

(b) Occupying existing homes or other structures in areas prone to rapidly moving landslides during periods of high risk due to heavy or extended rainfall;

(c) Conducting land management activities that may adversely alter the susceptibility of land to rapidly moving landslides; and

(d) Operating motor vehicles in areas known to be subject to rapidly moving landslides.

SECTION 4.

(1) In order to reduce the risk of serious bodily injury or death resulting from rapidly moving landslides, a local government:

(a) Shall exercise all available authority to protect the public during emergencies, consistent with ORS 401.015.

(b) May require a geotechnical report and, if a report is required, shall provide for a coordinated review of the geotechnical report by the State Department of Geology and Mineral Industries or the State Forestry Department, as appropriate, before issuing a building permit for a site in a further review area.

(c) Except those structures exempt from building codes under ORS 455.310 and 455.315, shall regulate through mitigation measures and site development standards the siting of dwellings and other structures designed for human occupancy, including those being restored under ORS 215.130 (6), in further review areas where there is evidence of substantial risk for rapidly moving landslides. All final decisions under this paragraph and paragraph (b) of this subsection are the responsibility of the local government with jurisdiction over the site. A local government may not delegate such final decisions to any state agency.

(3) Forest practice rules adopted under ORS 527.710 (11) shall not apply to risk situations arising solely from the construction of a building permitted under subsection (1)(c) of this section after the effective date of this 1999 Act.

(4) The following state agencies shall implement the following specific responsibilities to reduce the risk of serious bodily injury or death resulting from rapidly moving landslides:

(b) The State Forestry Department shall regulate forest operations to reduce the risk of serious bodily injury or death from rapidly moving landslides directly related to forest operations, and assist local governments in the siting review of permanent dwellings on and adjacent to forestlands in further review areas pursuant to subsection (1)(b) of this section.

SECTION 11. ORS 527.630 is amended to read:

(5) The Board shall adopt and enforce forest practice rules to reduce the risk of serious bodily injury or death from a rapidly moving landslide only in accordance with ORS 527.710 (11). As used in this subsection, 'rapidly moving landslide' has the meaning given in section 1 of this 1999 Act.

SECTION 12. ORS 527.710 is amended to read:

(11) In addition to its responsibilities under subsections (1) to (3) of this section, the Board shall adopt rules to reduce the risk of serious bodily injury or death caused by a rapidly moving landslide directly related to forest practices. The rules shall consider the exposure of the public

to these safety risks and shall include appropriate practices designed to reduce the occurrence, timing, or effects of rapidly moving landslides. As used in this subsection, 'rapidly moving landslide' has the meaning given that term in section 1 of this 1999 Act.

<u>SECTION 13.</u> ORS 527.714 is amended to read:

(5) If the Board determines that a proposed rule is of the type described in subsection (1)(c) of this section, including a proposed amendment to an existing rule not qualifying under subsection (3) of this section, and the proposed rule would provide new or increased standards for forest practices, the Board may adopt such a rule only after determining that the following facts exist and standards are met:

If forest practices continue to be conducted under existing regulations, there is monitoring or research evidence that documents that degradation of resources maintained under ORS 527.710 (2) or (3) is likely, or in the case of rules proposed under ORS 527.710 (11), that there is a substantial risk of serious bodily injury or death.

<u>SECTION 14 (2).</u> Sections 1 and 2, chapter 565, Oregon Laws 1997, are repealed when the State Board of Forestry adopts permanent rules implementing section 4 (4)(b) of this 1999 Act and the amendments to ORS 527.630 and 527.710 by sections 11 and 12 of this 1999 Act, or on January 1, 2000, whichever is later.

Department of Justice Opinion

Before Senate Bill 12 was adopted the Board had no authority to protect public safety or property from the effect of landslides on forestlands. (While the Forest Practices Act and other statutes gave the Board authority to protect forestland soil, water quality, and other forest resources, that authority did not extend to the protection of property and public safety.) One consequence of this limit on Board authority was that the Board, State Forester, and Department staff could not be held liable for failing to prohibit actions on private forestland which caused or contributed to landslides.

With the passage of Senate Bill 12, the Board not only has the authority to adopt forest practices rules relating to landslide hazards, it has the mandatory obligation to do so. This legislation has created a new landscape of legal liability. First, the Board is exposed to potential liability if it were to fail to comply with the legislature's rulemaking mandate. Second, the Department is exposed to potential liability for failing to "regulate forest operations to reduce the risk of serious bodily injury or death from rapidly moving landslides directly related to forest operations." Finally, Department staff are exposed to potential liability for negligence in administering the rules which the Board will adopt.

It is impossible to completely eliminate the risk of liability associated with a regulatory program whose goal is the protection of public property and safety in an area where hazards can never be entirely eliminated. However, to the extent that rules can be crafted which reduce the decision making burden on field staff who will be implementing the Board's policy, the liability risks can be reduced. There will inevitably be some tension between a "cookbook" approach, which is inflexible but more definite, and an approach which allows greater flexibility on the part of foresters but calls for judgments which might later be criticized as erroneous.

In considering new rules, the Board has broad discretion to interpret key statutory terms. Ultimately, new rules must be consistent with both Senate Bill 12 and the rulemaking provisions of the Forest Practices Act, ORS 527.714. The department will continue to discuss this issue with the Department of Justice through the rule development, so that unanticipated legal liability issues are minimized.

Findings Required (ORS 527.714)

Senate Bill 12 requires the Board to adopt new rules. The Board will have to make specific findings if the Board must either:

1. Implement provisions of the Forest Practices Act that grant it broad discretion or

2. Set standards for forest practices not specifically addressed in statute.

If such rules establish new standards for forest practices or increase current standards of forest practices, the Board must determine specific facts and standards listed in ORS 527.714 (1)(c) as follow:

1. Monitoring or research evidence documenting that there is a substantial risk of serious bodily injury or death if practices are continued under current regulations.

2. Documentation that the proposed rule reflects available scientific information, the results of relevant monitoring and, as appropriate, adequate field evaluation at representative locations in Oregon.

3. Documentation that the objectives of the proposed rule are clearly defined.

4. Documentation that the restrictions placed on forest practices as a result of adoption of the proposed rule are to reduce the risk of serious bodily injury or death, and are directly related to the objective of the proposed rule and substantially advance its purpose.

5. Consideration of the availability, effectiveness, and feasibility of alternatives to the proposed rule, including non-regulatory alternatives, and justification that the alternative chosen is the least burdensome to landowners and timber owners, in the aggregate, while still achieving the desired level of protection.

6. Documentation that the benefits in reduction of risk of serious bodily injury or death that would be achieved by adopting the rule are in proportion to the degree that existing practices of the landowners and timber owners, in the aggregate, are contributing to the overall resource concern that the proposed rule is intended to address.

V. GUIDING PRINCIPLES APPROVED BY THE BOARD

The Board of Forestry reviewed the draft work plan for this project at its April 21, 2000, meeting. With consensus of the Board, Chair Gilbert ordered: The Department is directed to follow the guiding principles as it implements the Landslides and Public Safety work plan, as contained in the agenda. Six guiding principles were approved, as follow:

Guiding Principle #1

Protection of the public can only be achieved through the shared responsibilities of homeowners, road users, forestland owners, and state and local governments.

Guiding Principle #2

Shallow-rapid landslides (the type that present the greatest risk to human life) pose the principal public safety threat that might be affected by forest operations. The regulation of certain forest practices, combined with other actions, can result in limited protection of the public. However, it is important not to mislead the public into thinking that such regulations will prevent all or even a majority of landslides in locations prone to rapidly moving landslides.

Guiding Principle #3

Public safety regulations should be risk-based, i.e., the greater the risk of physical injury to the public, the higher the appropriate standards for review of hazard and risk and also for control of practices which might affect the occurrence of, or impacts from, rapidly moving landslides.

Guiding Principle #4

Public safety regulations should minimize economic impacts on private landowners consistent with providing a risk-based level of public protection.

Guiding Principle #5

Where protection of public safety can be achieved more efficiently through means other than forest practice regulations, the department should facilitate these measures as resources permit.

Guiding Principle #6

Planning for land-management activities in landslide-prone locations should address two key questions: What is the inherent hazard at the site? Can the risk of damage to natural resources and the threat of personal injury be mitigated?

VI. SCIENCE

There is a very wide range in the certainty of the science as it relates to forestry and landslides. In this issue paper, an attempt is made to describe the level of certainty associated with the information presented. Three levels of certainty are described:

Strong scientific evidence means there is enough information to reasonably predict behavior of, in this case, a physical process. When sufficient and precise data are available, it is possible to reasonably predict behavior of the physical process. This applies best to homogenous (laboratory type) settings. Additional knowledge over time will still refine understanding of these processes.

Limited scientific information exists about many physical processes in the geologic environment. Heterogeneous field conditions that are difficult to sample make prediction of physical processes difficult. There is often some disagreement within the scientific community about these processes.

Best professional judgment based on scientific principles includes physical processes where there is little or no direct field data on these physical processes. Models may be developed, but not to the point where they can describe cause and effect relationships. For example, Peck (1967) describes the total inability to predict movement of a well-monitored landslide. Although there have been improvements since this time, we are far from the ability to reliably predict when landslides will occur, or if these landslides will become rapidly moving for very long distances. Therefore, many decisions are based on the judgment of field professionals.

Referenced Literature

There is an extensive body of literature on landslide mechanics. Only the most relevant and timely references are cited in this issue paper. The "Storm Impacts of 1996" study (Robison and others, 1999) is used extensively as a reference in this issue paper. Inventories based mostly on aerial photographs are generally not cited in this document, but are summarized in Robison and others (1999). In many cases, landslide inventories using only aerial photographs without significant on-the-ground surveying do not identify the majority of shallow-rapid type landslides because forest canopy obscures any ability to identify or accurately measure landslide areas (Robison and others, 1999). Therefore, landslide inventories based solely on aerial photographs have limited use for identifying those landslides most common in steep forested terrain, especially in areas with dense forest cover and are generally not referenced in this issue paper.

The "Storm Impacts of 1996" study is relied upon heavily in this issue paper because it:

1. Is the largest ground-based study conducted on forest lands in the Pacific Northwest;
2. Reflects current forest management practices on different landownerships in Oregon;
3. Is the only study to collect detailed information on stands of intermediate age (20 to 100 years); and
4. Is the only forest landslide inventory to quantitatively compare aerial photo inventories with ground-based inventories.

However, it is an inventory of single storm events, and therefore has several limitations:

- The combination of variation in storm characteristics (precipitation intensity and duration) and variation across the landscape to susceptibility of landsliding resulted in a range of hillslope and channel responses even within the February and November storm study areas. The focus of this study was on two individual storm events and therefore cannot be extrapolated to predict long-term conditions.
- The study focused on areas determined to have the most severe impacts from the 1996 storms, so results are expected to be well beyond the average forestland response to these individual storms.
- The study does not capture the total population of landslides that occurred as a result of these storms. The focus was on landslides that delivered sediment to stream channels because these landslides have the most significant effects on natural resources and public safety.

The "Storms of 1996" study did not attempt to answer mechanistic (cause and effect) questions. There are three study areas in Oregon (described below) where researchers are investigating mechanistic landslide questions. These researchers have attempted to understand the behavior of landsliding rather than compare rates between different age forests. This issue paper also relies extensively on research from these three study areas.

Faculty and graduate students from the University of Washington and the University of California, Berkeley have conducted research on the geomorphic, hydrologic, pedologic, and vegetation controls on shallow landsliding in a small study area northeast of Coos Bay, Oregon. All landslides in a 0.43 km^2 (.17 mi^2) that have occurred since it was clearcut logged in 1987 have been mapped (a total of 35 occurred up through 1996). Two hollows (or headwall areas) were instrumented, one recording just discharge at the downstream end, and the other fully instrumented to document precipitation, pore pressure, shallow groundwater flow in the soil and underlying rock (and their interactions), deep groundwater, chemistry of the runoff, and other physical processes. Both sites failed and produced debris flows, one in 1992 and the other in November 1996. Information from this study area was used to help develop a process-based model for delineating the topographic control on shallow landslide location (Montgomery and Dietrich, 1994; Montgomery and others, 2000). In total, seven Ph.D. dissertations have been completed based solely or partly on studies at this site, and 15 refereed papers that are based in part on this site (Dietrich, 2001) have been published, or are in press.

At a study site east of Eugene, the US Geological Survey (USGS) has installed a debris flow flume to evaluate the factors that influence debris flow initiation and movement. This flume is extensively instrumented, and has been used to generate many small debris flows. The flume has the ability to change and test individual parameters and to look at debris flow initiation and deposition processes (Iverson, 1997).

Landslide-prone terrain near the town of Mapleton has also been the focus of much study. Valuable research on debris flow movement after shallow-rapid landslide initiation comes from this area (for example, Benda and Cundy, 1990). This issue paper relies heavily on the aforementioned studies, since they provide current information and are directly applicable to the forestry and landslides issues in Oregon.

Landslide Occurrence

Landslides on Oregon's forestlands

Landslides are a dominant erosional process on steep, forested slopes in western Oregon (Swanson and others, 1987). A landslide is the movement of a mass of soil, rock, or organic debris downslope. The typical landslide on steep forestlands begins as a relatively small and shallow feature, with typical dimensions of 3 feet in depth, 30 feet in width, and 40 feet in length with a relatively planar failure surface (same shape as the ground surface) (Robison and others, 1999). These small landslides can initiate debris flows (a liquefied mass, scouring, or partially scouring, soils on the slope along its path). Upon entering stream channels, debris flows often carry large amounts of wood and boulders, and are referred to as debris torrents, at least in this issue paper.

There are many types of landslide processes. Earthflows and slumps, relatively slow-moving landslides, are common on less-steep slopes. In addition, there are rare events where entire mountainsides collapse and form rapidly moving landslides (for example, Mount Saint Helens during the 1980 eruption). However, these are not the landslides that have caused the concerns related to the forest management public safety issue. The relatively small landslides that occur on steep slopes are often referred to as "shallow-rapid landslides." Inventories have shown that forest management affects the occurrence of shallow-rapid landslides. These are the landslides that typically pose the greatest off-site public safety threat. They have also been called debris flows, debris avalanches, debris torrents, or rapidly moving landslides. An attempt is made to use terminology consistently in this issue paper. Terzaghi (1950) states "a phenomenon (landslides) involving such a multitude of combinations between materials and disturbing agents opens unlimited vistas for the classification enthusiast." Therefore, although attempts have been made to develop more standard terminology, other reports have used different terminology than used in this issue paper. A glossary of terms is found in Appendix 2.

Triggering mechanisms

There is strong scientific evidence that subsurface water and associated pore-water pressure within the soil are the most important factors associated with the occurrence of most landslides (Weiczorek, 1996). Pore-water pressure affects the inter-grain forces within the soil. The higher the pore-water pressure, the lower the effective strength. Landslides may occur if there is either an increase in shear stress and/or a reduction in shear strength along the failure surface (Cruden and Varnes, 1996) or they may fail as a result of soil liquefaction (where the slope, or a portion of the soils on the slope, behaves more like a liquid, usually due to a sudden rise in pore pressure, or a rapid loss of cohesion or cementation (Terzaghi and Peck, 1967; Andersen and Sitar, 1995)). Water is typically the triggering mechanism, at least for the landslides that most commonly affect forest land in Oregon. Earthquakes and volcanoes can also trigger landslides.

High subsurface water pressure is typically generated by large storm events, usually in the winter months (November through April). Snow melt, especially when combined with heavy rain, can add even more water to the slope. Even though forest soils are very porous, if enough water percolates into the soil, saturation can occur in limited locations.

Within any given storm, there is great spatial and temporal variability in the total amounts and intensities of rainfall and snowmelt (Surfleet, 1997; Berris and Harr, 1987). Therefore, landslides may be concentrated in relatively small areas within a storm track. Also, landslides may occur in small, isolated storm cells that may not be associated with major storms.

Increasing landslide susceptibility

Many processes can make slopes more vulnerable to landslides. The processes that make slopes less stable include: steepening the slope, loading the slope, reducing the strength of the materials within the slope, and altering drainage to allow more water into the slope. Over time, tectonic uplift and subsequent channel downcutting by streams make slopes steeper. Engineered cuts and fills (for roads and building pads, etc.) can result in greatly steepened slopes in the short term. Soil and rock weathering usually reduces slope strength and smoothes topography over time. Placement of loose fill, or loss of soil reinforcement by roots, may affect slope strength in a relatively short time period (1-10 years). Any activity or process that causes more water to flow into a slope usually increases the likelihood of a landslide.

As slopes become steeper, more of the earth’s gravitational force effectively acts in the direction of the slopes or potential failure plane (instead of perpendicular to the slope). Other things being equal, steeper slopes are less stable. Robison and others (1999) found that 84 percent of landslides surveyed that entered stream channels initiated on slopes steeper than 70 percent (35 degrees). Other studies have made similar findings. For example, Millard (1999) found that, depending on landform, minimum debris flow initiation slope steepness varies between 26 degrees (49 percent) and 39 degrees (81 percent). Slope steepness is an important factor to use in evaluating slope stability because there is strong scientific evidence that it theoretically explains landslide susceptibility. It has been found to explain observed landslide survey results and it is among the easiest site characteristics to measure.

Landform

Landform is a term that refers to the topographic shape of the ground surface. Since landslides on forestlands tend to be small, the landforms of concern in forests are also small. Sharply concave slopes, referred to as headwalls or "zero order basins," are found just above the locations where stream channels typically begin and form first order channels. These locations generally have landslide hazards because subsurface water flow is concentrated here (Dietrich and others, 1982).

Another landform with increased landslide hazard is the stream bank. Robison and others (1999) found that 34 percent of landslides surveyed were found adjacent to streams. Note, however, that the survey methods in this study (walking channels) were designed to find landslides in these locations and did not identify landslides that did not enter stream channels. Historical, large deep-seated landslide deposits are usually fairly easy to identify. Some parts of old landslides are often marginally stable, especially when undercut by streams or roads.

Landslides also occur on slopes with no apparent distinctive landform (other than steep slopes). Robison and others (1999) found that 41 percent of all upslope landslides occurred on slopes that were uniform or convex in shape. It must be noted that slopes seen as uniform in the field may in some cases be slightly concave. Therefore, although shallow, rapid landslides will occur preferentially in certain landforms, many landslides will also occur in areas with no outstanding features other than slope steepness.

Geology

Rock and soil properties are sometimes a very important control on the stability of slopes. Rock characteristics also affect soil development and soil properties, including strength. Rock joints and bedding create discontinuities in the slope that typically have lower strength than the rock mass (often much lower, sometimes lower than completely weathered soils). These discontinuities also affect the flow of water, and can both retard flow or direct a great deal of water to certain locations. Many studies have shown that landslides occur preferentially in certain geologic units (Rollerson and others, 1997; Brabb, 1984). Landslide susceptibility varies across Oregon. In part, this is related to differences in geologic units. The Tyee Core Area had the highest landslide occurrences found in the ODF Storm Impacts Study (Robison, and others, 1999).

Geologic process

The occurrence of landslides, including debris flows, is one part of the geologic process of landform development and evolution. Oregon is on an active continental margin and is greatly affected by plate tectonics. The coastal mountains are subject to relatively rapid uplift as the Plate of Juan de Fuca moves under the North American Plate (Orr and others, 1992). This same process has also produced the Cascade Mountains (through past volcanic eruptions). At the same time, weathering is acting to produce lower-strength materials in both mountain ranges. Most of the rocks in the Coast Range are subject to rapid weathering because they are mechanically weak and lightly cemented sand or mud; or fractured volcanic rocks. These rocks are inherently prone to rapid weathering.

The products of weathering can be moved downslope to more or less stable locations by a number of natural processes. These include creep (a slow gravity-induced movement), rolling, animal digging, and tree windthrow (displacement downslope with the root wad). The displaced soils (called "colluvial materials") tend to deposit in steep, unchannelized valleys (headwalls), at other slope discontinuities, and sometimes behind individual trees. Much of this sediment falls directly into the channel at the base of the hillslope.

Eventually, a storm of sufficient magnitude will occur and cause these steep slope areas to fail. If there is enough water in the failed mass, a debris flow may also occur immediately upon failure. Often, only a small portion (lower) of the steep headwall fails, leaving an even steeper un-failed slope above the failure (Robison and others, 1999; Montgomery and others [Figure 1], 2000). There is no clear agreement within the scientific community why these failures tend to be small, and why even steeper slopes often remain stable just upslope of these landslides. By logic, those upper slopes should be very unstable, since they have lost basal support during a period of high pore-water pressures. One possible explanation is water flow through fractured rock (Anderson and others, 1997), leading to very high localized pore-water pressure in the failed slope.

Effects of Forest Management Activities

Forest management practices may alter both physical and biological slope properties that influence slope stability and the occurrence of shallow, rapid landslides. Physical alterations can include slope steepening and loading (placement of weak fill material) and pore-water changes. Most physical alterations are the result of roads, skid trails, and landings. On a unit-area basis, roads have the greatest effect on slope stability of all activities on forestlands (Sidle and others, 1985). Biological alterations, usually in the form of changes in vegetation, can also have both hydrological and mechanical effects on the stability of slopes (Greenway 1987).

Timber harvesting

Storm Impacts Study findings

- Timber harvesting can affect landslide occurrence in areas with a high inherent landslide risk. Higher landslide densities and erosion volumes were found in stands that had been harvested in the previous nine years, as compared to forests older than 100 years, in three out of four

ODF storm monitoring study areas. Forested areas between the ages of 30 and 100 years typically had lower landslide densities and erosion volumes than found in the mature forest stands.

- There is significant landslide risk on very steep slopes regardless of forest age, especially in certain geologic formations, where major storms and landsliding processes are the dominant means by which a landscape is shaped.
- Landslides from recently harvested and older forests had similar dimensions, including depth, initial volume, and debris flow volume.
- Variability in both storm and site characteristics precluded the determination of significant differences by age classes.

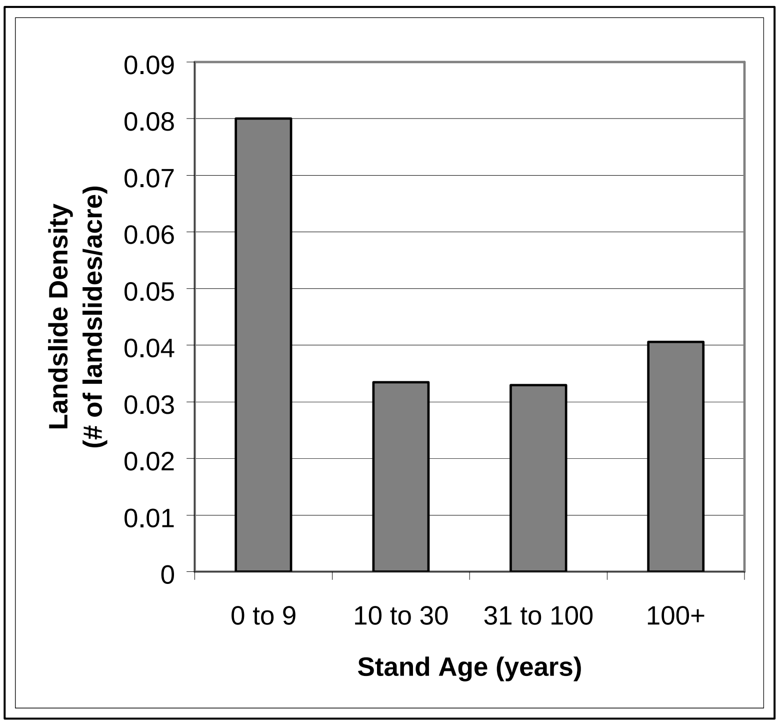

Figure 1. Landslide occurrence by stand age adjusted for slope for the 4 red zones combined.

Figure 1 shows landslide occurrence for four classes of stand age, combining data from the 4 red zone study areas (Robison and others, 1999). The data has been adjusted using only land area with slopes steeper than 60 percent. The raw data used to produce Figure 1 actually shows a great deal of scatter. The data in Figure 2 has not been lumped in to stand age classes and indicates the tremendous variation in year to year landslide density. Because of the other factors (including geologic and storm differences) affecting landslide density, a very large sample is needed to observe possible stand age effects.

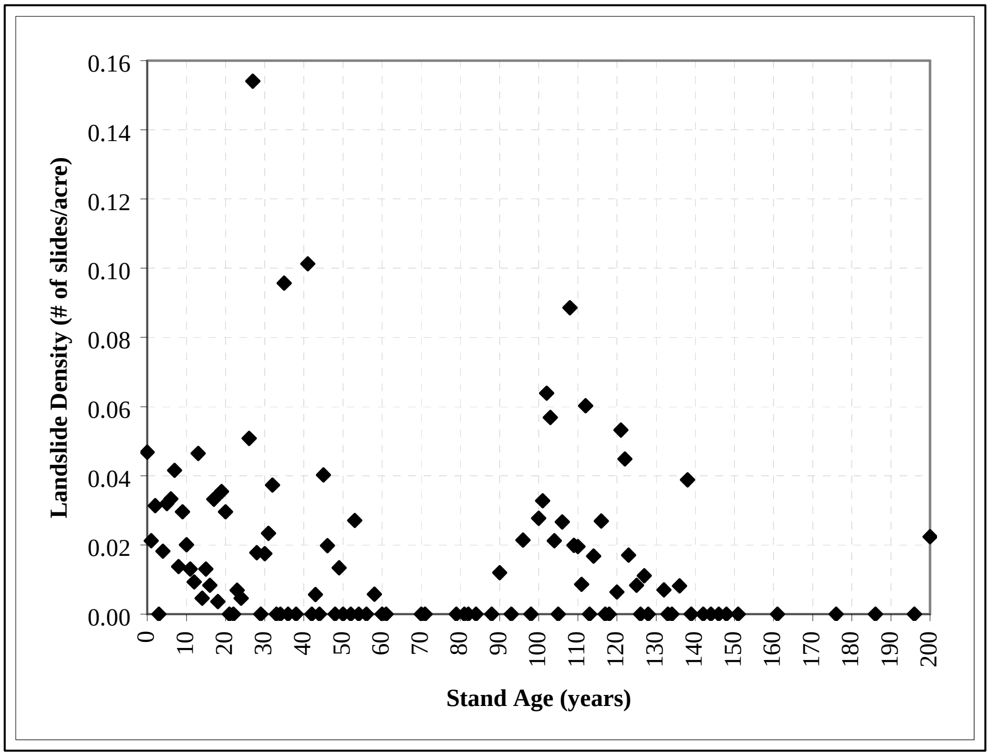

Figure 2. Raw data of landslide occurrence by stand age for the 4 red zones combined.

Root Strength

Since most landslide inventories have found a relationship between timber harvesting and an increased frequency of shallow-rapid landslides for some time period after logging, many researchers have assumed that the increase in landslides is due to a decrease in root strength (Sidle and others, 1985). There is direct evidence that root reinforced soil is stronger than the same soil without roots (Ziemer, 1981). Figure 3 shows the variance in relative root reinforcement with time after logging for both live and dead roots (Ziemer, 1981). Figure 3 is based on roots measured in a northern California mixed conifer forest. The drop in root strength at about 20 years is probably due to loss of Ceanothus (a shrub species) from canopy closure. Existing models have generally assumed that root strength acts in the same manner as soil cohesion, and that the tensile strength of roots can be added to the soil cohesion. Most root strength models also rely on the infinite slope equation, so they assume roots penetrate through the base of the landslide.

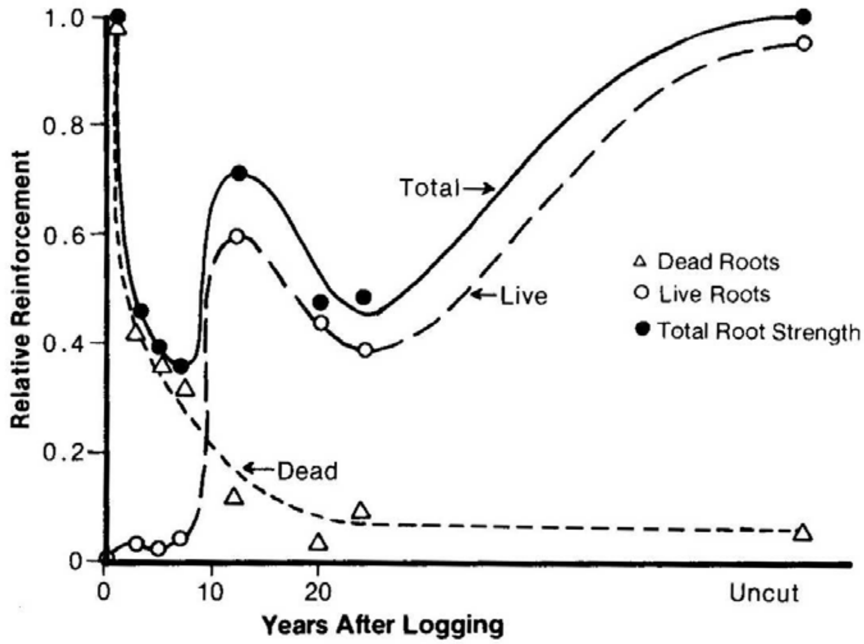

Figure 3. Root strength with time after logging [northern California] (Ziemer, 1981).

Most research on the effects of vegetation on slope stability has focused on root tensile strength. (Burroughs and Thomas, 1977). A very large body of scientific evidence concludes root strength is an important stabilizing mechanism on steep slopes. (Sidle and others, 1985). Much of the earlier scientific evidence is based on modeling and has not been hypothesis-tested using ground-based data applied to actual landslides (and areas that did not have landslides). Schmidt (1999) measured root characteristics at 41 sites in the Oregon Coast Range. He found the highest root strength in three test pits in natural forest settings. The lowest root strength values were found in three test pits in clearcuts where herbicides had been applied. Average rooting depth was constrained to the upper 0.5 meters of regolith (1.5 feet of soil).

Strength values cited in the technical literature and attributed to root reinforcement can, in some cases, lead to the conclusion that forested sites can't fail and all high risk sites that are harvested must fail (Skaugset, 1997), especially when analysis is based on basal root reinforcement. It is well documented from extensive ground-based landslide surveys that forested sites can and do fail (Hughes and Edwards, 1978; Ketcheson and Froehlich, 1978; Swanson and others, 1977; Robison and others, 1999). Dietrich (2001) points out that, even with high root strength, landslides can happen in forests according to those models if soil depths are sufficiently great over a wide enough area and also because gaps in root density occur in "forests" because of death and shading that can create local root strength gaps. After forests are cut, residual strength can be enough to withstand pore pressures from normal storms. Although in the past most models have considered basal root reinforcement, lateral root reinforcement is the likely important factor in the stability of steep forested slopes in the Pacific Northwest, as illustrated in Figure 4.

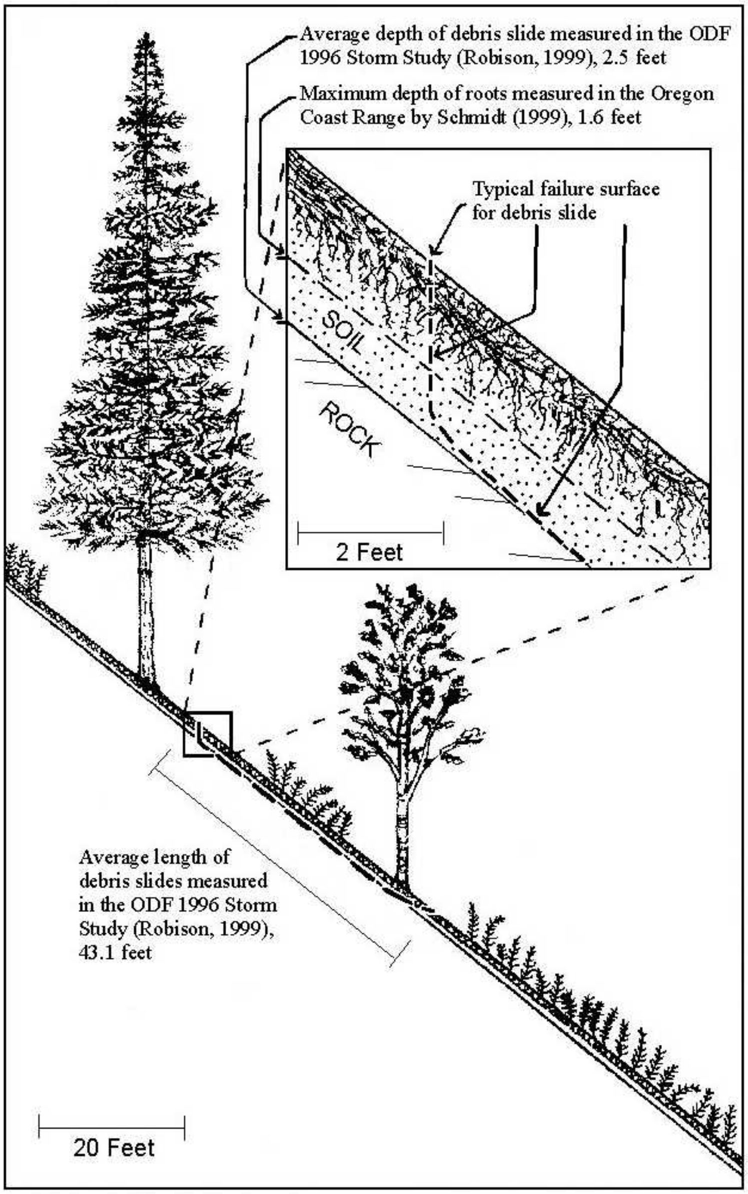

Figure 4. Maximum root depth and average landslide dimensions.

Basal root reinforcement is probably not a significant contributor to slope stability in coastal Oregon. Basal reinforcement occurs when roots penetrate the base of the landslide (usually into rock). Lateral reinforcement occurs around the edges of the landslide. Figure 4 indicates that any significant contribution to slope stability from roots probably comes from lateral root reinforcement rather than basal reinforcement. For average landslide dimensions, the best data available is found in the ODF 1996 Storm Study (Robison and others, 1999). For the maximum depth of roots, the best data available is found in Schmidt's (1999) dissertation.

Most root-strength studies have not adequately addressed the following issues:

- Strain compatibility differences between roots and soils (they reach ultimate strength at very different strains, so it is not mechanically correct to simply add both strengths together);
- In western Oregon, roots are not typically anchored through the basal failure surface, even though they are often modeled using the infinite slope equation, which only considers strength at the basal surface;
- The potential for slope failure through liquefaction; and
- The variability in root characteristics across the slope, and with depth (Greenway, 1987).

Other effects of vegetation

There are very few studies that deal with the potential hydrologic effects of vegetation removal on slope stability (especially studies in the Pacific Northwest). Landslide densities in Robison and others (1999) showed no delay in landslide occurrence after timber harvesting (Burroughs and Thomas, 1977) as would be expected if root strength were the only factor contributing to these higher observed landslide densities. And, while there was some variability on a year-to-year basis, stands younger than 10 years generally had elevated landslide densities (relative to the "100+" stands). For those stands greater than 10 years in age, a noticeable decline in the density was observed. Relatively low densities generally persisted in stands between 10 and 100 years old. This pattern might indicate that roots were not the dominant mechanism contributing to the reduced stability after timber harvesting, based on conventional root reinforcement theories.

It can be argued that increased landslide occurrence after timber harvesting may be due to changes in microsite hydrology. Reid and others (1997) found that the most rapid landslide liquefaction occurred after very short duration, high-intensity, simulated rainfall. Although there is no direct research on this issue, it is possible that a forest canopy may affect the delivery of "rainfall spikes" to the ground, thus affecting the potential for slope liquefaction. Forest canopy is usually measured in terms of the leaf area index, or the average surface area of all leaves, needles, branches and bole above any point on the ground. During periods of rainfall, the forest canopy probably stores moisture in proportion to the leaf area index. Even when canopy is saturated, water is stored for a short period of time. Megahan (1983) documents many subsurface hydrology changes and shows an average increase of 47 percent in maximum groundwater levels after vegetation removal (following clearcutting by helicopter and subsequent wildfire on granitic slopes) in Idaho.

In addition, while vegetation is generally thought to have a stabilizing effect on slopes, there are situations where it can have the opposite effect (Greenway, 1987). Wind loading on trees can result in dynamic loading on slopes, especially when trees blow down. Rogers and McHale 1999) measured increased pore-water pressure under stumps as they were rocked back and forth in the same manner that wind rocks a tree back and forth. Slopes can also become locally oversteepened as the overturning root wad displaces soil around the root wad. Often, blow-down occurs during very wet periods, so the local disturbance and dynamic forces may lead to liquefaction. The distribution of trees in any forest is far from uniform, so there are always openings where forest canopy and root density are lower. Slope failure should occur preferentially in locations where material strength is lower or water levels are higher.

In summary, there is strong, ground-based scientific evidence that removal of vegetation typically results in increased landslide occurrence on steep slopes in western Oregon (Hughes and Edwards, 1978; Ketcheson and Froehlich, 1978; Swanson and others, 1977; Robison and others, 1999). At the present time, there is limited scientific information on the relative importance of roots versus changes in microsite hydrology. Nor is there specific information on how to precisely model either root effects or canopy-related hydrologic effects. The role of roots versus changes in hydrology is important because forest management activities may have a different effect on roots as compared to canopy growth. Attempting to maintain roots and not canopy might not effectively mitigate the increase in landslide occurrence after timber harvesting if it is canopy that has the biggest influence on landslide occurrence. On the other hand, canopy and root growth patterns may be similar. In that case, it may not matter which mechanism is most important.

To help determine the potential effects of different forest management practices as they affect vegetation on steep slopes, a "Silvicultural Team" was formed. Based on Team discussions, a Silviculture and Landslide Susceptibility report was drafted and reviewed by the Team members (Appendix 3).

Forest roads

Roads create a contiguous linear physical alteration to hillslopes. To create the running surface, or tread, it is necessary to excavate into the natural hillslope (Figure 5). On less-steep slopes, this excavated material can be used as fill to make a portion of the running surface. The most common locations of road-associated landslides are 1) the cutslope; 2) the fillslope; and 3) below a culvert and below the fill (Figure 5). Prior to the mid-1980s, excavated soil and rock from full-bench road construction was generally sidecast onto very steep slopes immediately below the road prism. These steeply-sloped sidecast fills were often associated with landslides. Both cut- and fillslopes are steeper than the natural slopes, and, at least for some period of time after construction, are not vegetated. Thus, cut- and fillslopes have a higher landslide potential than the undisturbed hillslopes (Megahan and Kidd, 1972). In Oregon, road construction and maintenance practices requirements were changed in 1983 to reduce landsliding potential.

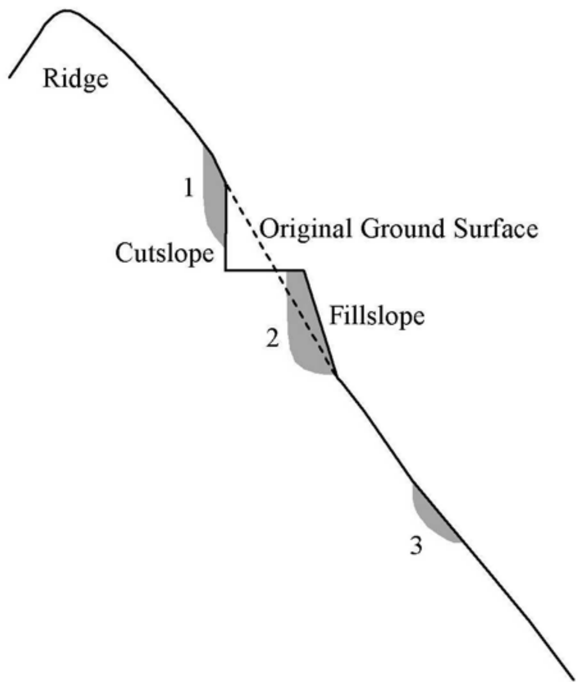

Figure 5. Locations of road-associated landslides.

Roads also alter the flow of water. Additional water is likely to result in increased pore-water pressure and a reduction in slope stability. Road cuts may intercept shallow groundwater, and the road surface normally collects surface water. This water is routed along the road to a location where it is discharged downslope of the road. Roads must also periodically cross streams. While most forest stream crossing structures are culverts, other designs include fords and bridges. During high flows, stream flows and/or road runoff can exceed culvert capacity, and bedload and floating debris may reduce or block the flow of water through the culvert. When drainage system capacity is exceeded, fill washouts, gullies, or landslides may occur in or below the fill, or further down the road. The concentration of road drainage can also be associated with interactions between road systems and channels in steep terrain, causing gullies and increasing the risk of landslides below culverts (Montgomery, 1994).

Storm Impacts Study findings

- Landslides that were associated with forest roads made up a smaller percentage of the total landslides in this study than the road-associated landslides did in most previous studies.
- The road-associated landslides identified during this study were smaller, on average, than road-associated landslides in past studies. However, these road-associated landslides were still several times larger, on average, than landslides not associated with roads.

- Landslides that delivered sediment to stream channels rarely occurred on roads across slopes of under 50 percent steepness, especially when roads had well-spaced drainage systems and fills of minimal depth.
- Road fill placed on steep slopes creates an increased landslide hazard even where no drainage water is directed to those fills.
- Road drainage waters directed onto very steep slopes create an increased landslide hazard even when there is no road fill placed on those very steep slopes.
- Road-associated landslides were wholly or partially associated with a large percentage of the highly impacted stream channels (from debris torrents) in three of the study areas.
- Based on the low numbers of road-associated landslides surveyed in this study and on the smaller sizes of these landslides (as compared with previous studies), current road management practices are almost certainly reducing the size and number of road-associated landslides.

Other forestry activities

There is very little field-based information on how the effects of practices like herbicide application or slash burning affect landslide occurrence (Pyles and others, 1998). Schmidt (1999) found that root strength was lowest on sites that were cut and then sprayed with herbicides. Landslide and debris flow occurrence is often associated with wildfires. This effect may be due to changes associated with loss of vegetation, or because of soil property changes caused by intense heat and resultant hydrophobic soils. There is no clear consensus on how, or if, this process affects landslides and debris flows in coastal Oregon.

Rapidly Moving Landslides

Senate Bill 12 defines rapidly moving landslides as "difficult for a person to outrun or escape." It would be reasonable to interpret this to mean faster than 2 to 5 miles per hour. Debris flows typically move at velocities exceeding 10 miles per hour (Benda, 1985). This is a velocity where structural damage or collapse may occur if the landslide hits a building or vehicle. Although the lower limit of fatality-producing landslides has not been well defined, this velocity (2 to 5 miles per hour) would include all fatalities listed in Table 3.6 of Cruden and Varnes (1996). In addition, the velocity of landslides can be expected to change as they move downslope, especially near the location where they stop.

In steep terrain, small, shallow landslides can quickly transform into debris flows. A debris flow occurs if the landslide moves downslope as a liquefied mass, scouring, or partially scouring, soils on the slope along its path. A debris flow is any movement below the initial landslide and upslope of a stream channel. Upon entering and continuing down a stream channel, debris flows are called debris torrents (Van Dine, 1985; Robison and others, 1999). In western Oregon, landslides initiate most debris flows and torrents (Swanson & Lienkaemper, 1978). Debris torrents in the Pacific Northwest are different from channelized debris flows in other regions because, in addition to boulders, they typically contain significant amounts of large wood.

Debris flow initiation

Since most landslides that occur on forestlands begin as small features, the factors that cause these small landslides to become large, rapidly moving debris flows are of critical importance. Unfortunately, the scientific information on this issue is limited. We do know that some (perhaps many) landslides on steep slopes do not become debris flows. Unfortunately, the landslides that do not become debris flows are even more difficult to identify, even in recently harvested areas, since they can be very small (Robison and others, 1999).

The availability of water, slope steepness, sources of additional debris (soil, boulders, and/or wood), lack of internal drainage, higher soil porosity, and lateral confinement appear to be the most important factors leading a small landslide to become a debris flow (Iverson and others, 1997; Davies, 1997). Robison and others (1999) did not find any debris flows that initiated on slopes under 40 percent steepness. Landslides that started on slopes over 70 percent steepness initiated most inventoried debris flows. Slope is a critical factor in developing momentum in these landslides, as is water availability (Benda and Dunne, 1997). As the debris flow initiates, this water is probably related to liquefaction of the initial landslide mass. The more water in this initial landslide mass, the greater potential for liquefaction. Thus, soils with a great deal of pore space that is at or near saturation should be more likely to produce debris flows.

The location on the landscape can have a great influence on whether a shallow-rapid landslide becomes a debris flow. Millard (1999) found that headwalls are more likely to initiate a debris flow once a landslide occurs, and that these debris flow-producing landslides occur on less-steep slopes within headwalls (as compared to side slopes). A study of 24 debris flows in natural forests of the Oregon Coast Range found that they were all initiated by landslides in headwalls at least 140 feet below the drainage divide (Pierson, 1977).

Debris flow movement

Debris flows move downslope as one or more unsteady and non-uniform surges, sometimes transporting boulders larger than 30 feet in diameter (Iverson, 1997). Those typically associated with heavy rains in Oregon move smaller materials (up to 5- to 10-foot diameter boulders and logs). Debris flows can rapidly entrain material and grow in size as they move downslope. Robison and others (1999) found that the material scoured along debris flows or torrent paths, and not the initial landslide volume, represented over 60 percent of the landslide-related sediment carried into stream channels. A source of debris that can be entrained by the debris flow must be available for debris flow movement and bulking. It is likely that relatively loose material containing a variety of particle sizes makes the most suitable debris flow material.

There is limited scientific information on debris flow scouring and bulking processes. Lack of internal and external drainage as the debris flow moves down steep hillslopes of channels seems to be necessary for debris flow movement. Water tends to drain rapidly from landslides that do not contain fine materials. Related to lack of drainage is confinement. Confinement refers to a narrow, linear depression in the landscape (a hollow or canyon). Debris flows tend to dissipate if they spread laterally. Concave landforms such as swales, channels, or draws can physically confine debris flows and keep their energy from dissipating. Debris flows can also scour uniform hillslopes and therefore create their own confinement.

Channelized debris flows or debris torrents

In some cases, an initiating landslide of 10 cubic yards or less may become a debris torrent moving thousands of yards of material into and through extensive portions of the channel network (Figure 6). However, even in the ODF study, one-third of landslides were failures of the stream bank (not debris flows or torrents), and an additional 10 percent of the debris flows stopped at or near the channel (did not become the more dangerous debris torrents).

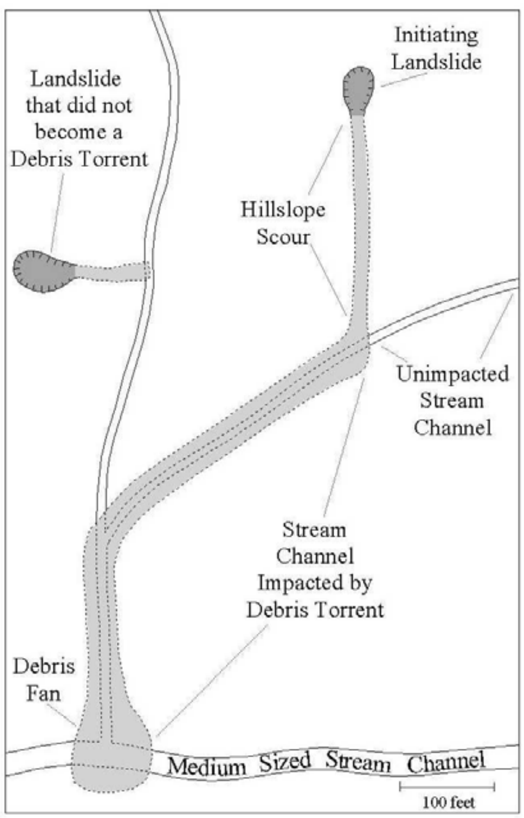

Figure 6. Initiating landslides and resulting debris flows and torrents.

Upon entering stream channels, debris flows have probably increased greatly in both momentum and volume. In the stream channel, there may be a much larger source of water to affect debris flow movement. Debris (wood, boulders) in the channel can also be incorporated into the debris torrent. Confinement is critical for debris torrent movement in channels. Typical Oregon debris torrents travel long distances (thousands of feet) down relatively gentle channel gradients and away from steep hillslopes.

May (1998) looked at debris torrents that reached fish bearing stream channels (moved long distances) in the Siuslaw River watershed. These long running debris flows often included road-associated landslides that were much larger than the other landslides. Long running debris flows disproportionately came from recent clearcuts (46 percent of the initiating landslides). Multiple initiating landslides, debris left in channels and younger riparian forests may all be factors that increase potential debris torrent movement distances (May, 1998; Robison and others, 1999).

When channels become wide, debris flows typically spread out laterally and quickly lose momentum and behave more as a flood (leaving the large boulders behind). Channel junctions can also affect debris flow momentum and cause them to cease movement (Benda and Cundy, 1990). Channel junctions tend to stop debris torrents because of decreased channel gradients and the loss of momentum due to the change in direction.

Debris torrent deposition

Debris torrents in the Oregon Coast Range, which tend to be of relatively small to moderate size, usually stop in close proximity to sharp channel junctions (an angle of 70 degrees or greater to the receiving channel) (Benda and Cundy, 1990; Robison and others, 1999). The Benda-Cundy model uses channel gradient and junction angles to evaluate debris torrent deposition. Channel confinement also has a major effect on debris torrent movement. Debris torrents may cease movement at a wide range of channel gradients. In British Columbia, debris flows seem to stop at much steeper gradients than they do in Oregon (Van Dine, 1985; Fannin and Rollerson, 1993). This may be due to greater channel confinement and a greater percentage of fine soil material in the Oregon debris flows.

Debris flows that become unconfined will tend to cease movement. The channel width required for confinement depends on the volume of the debris flow. Very wide valleys can confine very large debris flows. In this way, debris torrent volume interacts with channel confinement to greatly influence debris flow travel distance. Iverson and others (1997) found fairly simple relationships for determination of area impacted by debris flows that depend on the volume of the debris flow and valley geometry. Predicting the debris flow/torrent volume is another matter. Given the many factors that influence debris flow movement and growth, current scientific tools are in no way predictive of debris flow or torrent volume.

Factors that provide obstructions to the debris torrent will probably reduce its momentum and cause it to begin to cease movement on less-steep gradient channels. Debris flows have been observed to stop at or near road fills across the channels in their path. Large boulders and channel constrictions can also reduce debris torrent momentum in these lower gradient areas. It is widely believed that large trees in or along the debris flow path may also act to slow debris flow momentum in these lower gradient areas. Note, however, that the Rock Hubbard debris torrent traveled about a quarter mile down a moderate gradient (about 20 percent steepness) section of channel lined with "old-growth" forest before destroying a home.

Storm Impacts Study findings

- Stream channel impacts varied greatly by study area. Impacts were not directly related to the number of landslides. Large, upslope landslides that enter stream tributaries with small horizontal stream junction angles and steep channel gradient slopes resulted in the greatest stream channel impacts.
- The Benda-Cundy model provides a reliable tool for determining maximum potential travel distances of "typical" debris flows and torrents from forested slopes. Less than 10 percent of the total landslides traveled further than predicted by the Benda-Cundy model. This means channel junction angles and channel gradient are important factors in determining maximum landslide run-out distance.
- The debris torrents that traveled further than predicted were, on average, larger and had younger riparian vegetation near their terminus, indicating that landslide volume and composition of the riparian area along debris torrent-prone channels may be important secondary factors in determining landslide run-out distances.

Note that debris torrent confinement was not evaluated in great detail as part of this study. Therefore we have little data on one of the important factors that affect debris torrent movement and run-out distance. Additional data is currently being collected (see Appendix 4).

Debris flow/torrent impacts

The impact from a debris flow or torrent on objects in its path depends on the size (volume) of the debris torrent, the velocity at the point of impact, and the proximity of the affected object to the debris torrent. Debris flows and torrents vary widely in size. The average debris flow volume for the ODF study was 509 cubic yards, with a maximum of 32,000 yards within the study areas (a 60,000 cubic yard debris flow occurred just outside the Vida study area). Larger debris flows are more mobile and typically move longer distances from steep slopes (Corominas, 1996). Debris flows associated with very large initial landslides or volcanic eruptions can be several orders of magnitude larger (Iverson and others, 1997) and are, therefore, far more dangerous. However, these large landslides are not the shallow-rapid landslides that research has shown can be influenced by forest management.

Where people are located relative to a debris flow has a major influence on the public safety risk. During the concluding presentation at the First International Debris Flow Hazards Mitigation

Conference, Davies (1997) states "the risks attending occupation of debris flow-prone areas can be entirely eliminated by ceasing their occupation. The risk to human life can be almost entirely eliminated by prohibiting dwellings in the risk area, and allowing only extensive use, e.g., for agriculture." Within canyons, debris flows typically are moving very rapidly, and pose extreme risk to persons in the base of these canyons. Unfortunately, in many areas, dwellings and roads already exist in high hazard areas. The house destroyed in the 1996 Rock Hubbard debris torrent was near the center of a confined canyon, and was completely obliterated by the debris torrent. Vehicles were trapped on Oregon Highway 38 below a location where the highway was cut into a debris flow channel (locally oversteepened). A car was completely destroyed by this debris flow, and at least one large truck was badly damaged. Homes at the top of the debris fans are also at high risk of major debris torrent impacts, while homes on the sides of fans, or at the terminal end of the fan are more likely to experience low-velocity impacts (mud and water damage).

Also, while woody debris carried in debris flows torrents may have long-term benefits for aquatic habitat, it can create a public safety hazard in some cases. Harvey and Squier (1998) found that “slash piles in the channel, or abundant slash, which can form temporary debris jams in the channel, can increase the severity of debris flows.” Wood is also associated with “migrating organic dams” that can move long distances down relatively gentle stream channels (Coho and Burges, 1994). Migrating organic dams can have similar impacts to streams and property as debris flows, but are usually moving slow enough for people to escape.

VII. RISK REDUCTION STRATEGY

Hazard versus Risk

The forest practices definitions refer to the terms “high risk areas” and “high risk sites.” The term "hazard" is not used in the forest practice rules. The difference between hazard and risk is often not well understood. Hazard refers to the inherent susceptibility of a given location to some event that could produce negative consequences (in this case, the likelihood that a landslide or debris torrent will occur). Risk is the likely consequence associated with the occurrence of a hazard negatively impacting a valued resource. Risk assessment must take into account multiple hazard locations (as is commonly the case for most debris flow-prone locations). Vulnerability is used to describe the degree of loss within the landslide-affected area (Finlay and Fell, 1997). Landslides can occur and have no effect on resources. When landslides become debris flows/torrents, they can have both negative and positive effects on fish habitat (Reeves and others, 1995). However, if people are present along their path, debris flows and torrents can only have negative effects and pose a risk to these people.

Hazard and risk depend on a great many factors. For example, very steeply-sloped areas with confined stream channels in the Tyee Core Area can have very high debris flow hazard. If no people are in or below these areas, however, there is no public safety risk. Public safety risk, therefore, depends on the population in these locations during extreme rainfall periods, including the number of people, and their proximity to dangerous locations.

Reducing the Incidence of Rapidly Moving Landslides

Steeply-sloped areas that are common in some parts of Oregon pose a high natural hazard of rapidly moving landslides. Therefore, it is not possible, or even feasible, to prevent the occurrence of all such failures. However, steps can be taken so that the hazard is not greatly increased. Preventing the physical steepening of slopes (typically by road construction) is of critical importance. Not redirecting water to steep or hazardous slopes is also important. Maintaining roots and canopy on these steep areas will reduce the incidence of landslides, at least over the short term. Finally, in terms of vegetation management, dense stands seem to have a lower hazard of rapidly moving landslides. Forest practices options for reducing landslide incidence are discussed in Section IX of this Issue Paper.

Reducing Population at Risk (Exposure)

Subsection 3(3) of Senate Bill 12 states "Although some risk from rapidly moving landslides can be mitigated through proper siting and construction techniques, sites that are vulnerable to impact from rapidly moving landslides are generally unsuitable for permanent habitation." Risk to people depends on a number of factors. First is the incidence of landslides on slopes prone to debris flows. Shallow-rapid landslides typically begin on very steep slopes (over about 70 percent) during periods of unusually intense rainfall. Therefore, to be at risk, people need to be in some proximity to these steep slopes during very wet periods. If people are present in debris flow-prone areas during very wet periods, specific risk depends on their location relative to the debris flow path, and how a dwelling or vehicle might protect them. Persons in confined canyons are at greatest risk, those on debris fans are at high risk, and those at the base of unchannelized steep slopes are at substantially lower risk.

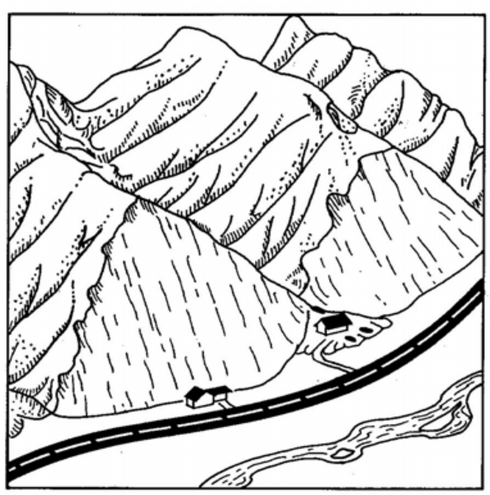

Figure 7. Homes and road in debris flow-prone locations (on a debris fan and at the base of a steep slope).

The size of the initiating landslide, the water available (storm intensity), channel (or path) characteristics, and debris availability may all, to some extent, affect how far and how fast a debris flow will travel. Many debris flows stop when they reach a small stream channel, and never get close to populated areas.

Independent and department investigations of fatalities associated with landslides

After the debris torrent-related fatalities in November 1996, the department concluded it was necessary to conduct both a departmental and an independent investigation of the events contributing to these two debris torrent-related tragedies. The independent investigation (Harvey and Squier, 1998) found that:

- The November 1996 storm was the most dangerous (highest 24-hour rainfall total) "triggering storm" event for debris slides/debris flows in recorded history at both the Rock Hubbard and Oregon Highway 38 sites [note that the Rock Hubbard landslide occurred during the middle of this storm];
- Clearcutting on these steep slopes mantled with shallow soils resulted in a "12-year" window of lowered stability on both the Rock Hubbard and Oregon Highway 38 sites, and increased both the risk and probability of a debris slide/debris flow event;
- Slash in the upper Rock Hubbard channel appeared to result in temporary debris dams, where temporary blockage and then breaching of these dams would increase the potential energy and size of the debris flow; and
- The one residence was sited in an extremely hazardous area on a debris flow fan built up over time by a series of debris flow events.

The department investigations determined that both landslides occurred within, or at the boundaries of, recent timber harvest units. Neither landslide was associated with roads, or alteration of surface drainage patterns, or gouging of the ground surface. Thus, there were no rule violations (of the rules in place at the time of the operation) associated with these two landslides. Both landslides occurred during the period when increased landslide frequency after harvesting (shortly after cutting) is frequently, but not always, observed on steep slopes.

Evaluating risk of serious bodily injury

A number of factors affect the risk from rapidly moving landslides, including the:

- Recurrence frequency of debris torrents in the affected location;
- Velocity, size, and composition of the debris flow/torrent;
- The precise location of population in relation to the debris torrent path;
- Time people spend in these dangerous locations; and
- Protection afforded by buildings or vehicles.

To reduce debris flow risk to people, at least over the long term (decades), requires that the time they spend in debris flow-prone locations is reduced (during periods when debris flows are possible). While moving, individual vehicles have a fairly small exposure to debris flow hazard (though overall risk can still be fairly high on very busy roads). For the Oregon Highway 38 fatality, vehicles were trapped behind another landslide for hours, greatly increasing the exposure of those motorists. In homes, people are typically exposed to hazards for much longer periods of time. Homes in canyons are at especially high exposure, and there are often no safe escape routes for residents (thus the Rock Hubbard tragedy). Fortunately, most debris flow-prone canyons are too narrow to have allowed home construction. However, homes on debris fans are far more common in Oregon and still face a substantial risk from rapidly moving landslides.

For homes, therefore, it will be necessary to reduce (or, at least, not increase) the time people spend in precariously sited homes during dangerous periods. This can be achieved in some cases by educating people on what conditions make them vulnerable, and what storms are likely to produce dangerous landslides. Other alternatives can be more permanent. One viable option is to prevent rebuilding in dangerous locations after buildings are destroyed by debris flow (Section 5 of Senate Bill 12 (1999) now allows local governments to prohibit reconstruction of homes destroyed by landslides). However, Senate Bill 12 may prevent local governments from prohibiting new home construction in these locations. The most effective technique, however, is when homeowners are willing to sell, those homes would be purchased and either moved or removed from dangerous locations.

Relative risk of different activities

There are risks associated with many everyday activities. These risks can be expressed as the average number of fatalities per year or by exposure (i.e., million miles traveled). Statistics are compiled on many of these risks. Examples of common high risk activities include smoking cigarettes, mountain climbing, travelling in a car, and working in the mining industry. For most persons, the risk of death or serious injury from landslides is very low compared to these other risks.

There are several ways to calculate the risk of fatality from landslide-initiated debris flows or debris torrents in Oregon. The method used in this section of the issue paper was to determine the number of people killed by debris flows and debris torrents historically and then use that number to calculate a fatality rate. Fatality rate is expressed as the average number of people killed by debris flows and debris torrents per year in a given area per capita.

Other state and federal agencies have not compiled extensive landslide fatality statistics. Even regional and local historical societies do not have much information related to this subject. For this project, a thorough review of newspaper archives at the State Library was combined with in-house knowledge to determine the historical occurrence of landslide-related deaths in Oregon. Newspapers printed on, and immediately after, dates of extreme winter storms were searched for articles describing landslide events. Many news stories mentioned landslides, but did not provide much detail. Often articles would state that "slides swept several cars away," but there would be no mention of what happened to the occupants of those vehicles. Undoubtedly, some deaths and injuries related to landslides are misreported or unreported. However, a record of nine separate events, occurring after 1880, in which a total of 25 people were killed by debris flows or torrents were documented. Table 1 lists locations, dates, and descriptions of each event.

The historical records of landslide fatalities in Oregon predating 1950 are inconsistent. The lack of records of landslide fatalities from 1909 to 1953 does not mean that there were no landslide fatalities during that time period. Rather, it is assumed that landslide fatalities did occur during that time period, but went unrecorded or were poorly recorded. For that reason, the following analysis focuses on the historical records from 1950 to the present.

At least 21 debris flow/torrent fatalities have occurred in Oregon since 1950. Two of the 21 fatalities involved persons traveling in automobiles. At least nine of the 21 fatalities occurred to persons on the job, two-thirds of those being employed by logging operations. Nine of the 21 fatalities occurred to persons in or near a home. The debris flow/torrent death rate averages about one death every five years for the entire population of Oregon.

Table 1. Debris flow/torrent events resulting in fatalities, in chronological order

Location	County	Date	Description
Mapleton	Lane	February 1890	3 people killed in or just outside home
Columbia River Gorge	Multnomah	November 1909	Train hit slide, engineer killed
Toketee Dam	Douglas	Winter 1953	3 workers killed
Remote	Coos	December 1955	5 killed in home
50 miles SE of Eugene	Lane	January 1963	4 loggers killed
Southern Oregon	Curry	March 1972	1 man killed in car
Pollalie Creek	Hood River	December 1980	1 camper killed
Rock Hubbard	Douglas	November 1996	4 people killed in or just outside home
Oregon Highway 38	Douglas	November 1996	1 woman killed in car
Fiddle Creek	Douglas/Lane	February 1999	2 loggers killed

(Note that the landslide causing the most fatalities (9) in Oregon's recorded history was not a debris flow. It was a larger deep-seated landslide that occurred near Canyonville in 1974.)

Most people in Oregon are not at significant risk to debris flows and debris torrents. However, there are small segments of the population consisting of persons that live or work in areas known to have high, or even extreme, debris flow and debris torrent hazard. To calculate the risk of a debris flow/torrent fatality for different scenarios, the death rate for each scenario was multiplied by the relevant population. Risk is often expressed as the number of people in every 100,000 people likely to die on an annual basis. Table 2 displays the results of this risk analysis for several different scenarios including living in high or extreme hazard areas of Lane, Douglas, and Coos Counties.

Table 2. Hazards and associated risks in Oregon.

Hazard	Risk (likely # of deaths per 100,000 people per year)	Number of Deaths
DEATH FROM DEBRIS FLOWS OR DEBRIS TORRENTS		
Running into or being hit by a debris flow/torrent while driving in Oregon	0.002	2
Living, driving or working in Oregon	0.02	21
Living in High Debris Flow Hazard in Lane, Douglas, or Coos County	3	5
Working as a logger in Oregon in Lane, Douglas, or Coos County	3	6
Stopped in an automobile on Highway 38 in an extreme storm event	50*	1
Living in Extreme Debris Flow Hazard in Douglas County	70	4
DEATH FROM OTHER CAUSES		
Lightning strikes (nationwide)	0.033	
Flash floods (nationwide)	0.05	
Traveling in a motor vehicle (Oregon)	13.7	
Smoking cigarettes (Oregon)	198.2	
Heart disease (Oregon)	233.1	
All causes (Oregon)	893.7	

*Calculated for the stretch of highway between mileposts 7 and 16.
If the number is expressed as per storm event, it is 2000.

The number of homes in high hazard areas of Lane County was calculated by performing a GIS query of homes and ODF debris flow hazard ratings. The number of homes in high hazard areas of Douglas County and Coos County was estimated based on extensive field experience and knowledge of those rural populations and how they compare to the rural population of Lane County. The number of homes in extreme hazard areas of Douglas County and Coos County was determined using USGS quads and field validation. The number of occupants per home was assumed to be three people.

Table 2 also shows the risk assessment for Oregon loggers, Oregon drivers, and vehicles stopped on Oregon Highway 38 during extreme storm events. The risk for loggers was calculated using an estimated average number of loggers employed in Lane, Douglas, and Coos Counties over the past 50 years. The number used was 4,000. The risk for Oregon drivers was calculated using Oregon's current population for a time period of only 30 years.

The risk for vehicles stopped on Oregon Highway 38 during extreme storm events was a unique situation. Average vehicle risk is a term used to evaluate the percentage of time that a vehicle will be present in a dangerous location (Wyllie and Norrish, 1996). It was developed for rock falls, another kind of rapidly moving landslide, but is equally suitable to debris flows.
Average Vehicle Risk, or AVR, is equal to:

$$\frac{\text{Average daily traffic (cars per day)} \times \text{road length exposed to hazards (miles)} \times 100\%}{\text{Speed Limit (miles per hour)} \times 24 \text{ (hours in a day)}}$$

If traffic is moving at normal speeds, it takes many miles of hazardous area to make the risk high. Note, however, that if the traffic is not moving, the bottom term is zero, so in effect the risk is very high. It cannot be calculated by the equation; it depends on how long and where the cars are stopped. An example of a very dangerous situation occurred on Oregon Highway 38 during the November 1996 storm. Many motorists (dozens of vehicles) were trapped, stopped by a smaller landslide blocking the highway. Several were waiting at the mouth of a steep canyon, when a debris flow occurred and moved the vehicles, pushing one into the Umpqua River.

The risk for vehicles stopped on Oregon Highway 38 during extreme storm events was calculated using data from the department's '96 Storm Study. Roughly 2.6 percent of the roadway on Oregon Highway 38 through the extreme hazard area of Douglas County was inundated by debris flows and debris torrents during the November 1996 storm event. Any car stopped in that extreme hazard area on Oregon Highway 38 had a 2.6 percent chance of direct impact from a debris flow or debris torrent.

Table 2 also shows the risk of death from other hazards for comparison. The numbers for flash floods and lightning strikes were taken from a National Oceanic and Atmospheric Administration National Weather Service preparedness guide on the internet. These numbers are calculated annual averages for the entire country and the numbers for Oregon are probably different. The numbers for the risk of death from traveling in a motor vehicle, smoking cigarettes, heart disease, and all causes were taken from the Oregon Health Division's 1997 Oregon Vital Statistics Report and these numbers are for the year 1997 in Oregon.

Table 2 shows that the risk of death from debris flows and debris torrents is several orders of magnitude greater for the small segments of the population known to be living, working, or travelling in areas of high or extreme hazard compared to the general population of Oregon. When compared to other more commonly perceived risks, the risk of death from debris flows and debris torrents is low for the average Oregonian, but high for those persons in areas of high and extreme debris flow/torrent hazard. It is also important to note that debris flow/torrent injuries greatly outnumber the number of deaths and often these injuries are quite serious. However, the injuries are less likely to be recorded compared to fatalities. For example, approximately 50 landslide-related injuries are estimated to have occurred in 1996 in Oregon compared to the 5 fatalities that occurred that year. Naturally, the injuries received much less attention than the fatalities.

An estimation of the effects of forest management activities on risk will be made using the aggregated "Storms of 1996" study data. An attempt will also be made to assess the effects of down wood and younger riparian vegetation as part of this estimation. This information is found in Appendix 4 (under development).

Determination of Substantial Risk

ORS 527.714(5) requires the Board to determine that there is a substantial risk of serious bodily injury or death before adopting proposed rule for landslides and public safety.

ORS 527.710 (11) states that "the rules shall consider the exposure of the public to these safety risks and shall include appropriate practices designed to reduce the occurrence, timing, or effects of rapidly moving landslides."

In a paper on landslides and acceptable risk, Finlay and Fell (1997) state that "society in general and individuals within it face various risks. These cannot be eliminated, only reduced by applying additional resources." They note that individuals and society are far less accepting (up to 3 orders of magnitude) of involuntary risks than risks undertaken voluntarily. The acceptance of risk depends on many factors, including: the benefits to the individual from taking the risk; whether the risk is known or unknown to the individual; whether the risk is caused by a person or is a "natural" risk; and the scientific or cultural understanding of the link between the hazard and the risk to the individual.

Economic trade-offs are commonly accepted at some level, even when parties may have very little choice. However, the level of acceptable risk is typically much lower in these cases. An example of acceptable risk where the population at risk has little control is the risk of a serious accident from slow moving farm equipment traffic on roads. The economic benefits from slow moving farm equipment apparently exceeds the added risk to the public from unexpected, large equipment in the roadway. On the other hand, smoking statistics alone are not appropriate for comparison because they reflect individual choice of acceptable risk.

In the case of persons living below steep slopes, there is a natural high risk that can be further elevated by forest management activities. There are many residents in these areas that probably had little understanding of the risk when they purchased their home. After the storms of 1996, many people probably have a greater understanding of the risk than when they acquired their properties. Although these people may have accepted the risk associated with natural hazard, they probably do not want to accept the increased risk associated with forest management activities. Therefore, the final determination of substantial risk is to some extent a policy choice for government. In this case, it is a decision that the Board of Forestry must ultimately make.

The closest analogy to rapidly moving landslides where acceptable risk has been considered by a government appears to be for dams. The Australian Committee on Large Dams adopted the following criteria for new dams and for the upgrading of existing dams:
1) An objective of one death per million people per year, and one death per 100,000 people for the person at greatest risk; and
2) A limit of up to ten times the objective fatality rate if risk reduction is impracticable or if the cost is grossly disproportionate to the improvement gained.

Debris Flow/Torrent Mitigation

A number of strategies have been used to reduce public safety risk around debris flow deposition areas. Typically, these measures include:

- Check-dams in the debris flow channels, designed to retard debris flow movement;

- Channelization in the debris flow fan to direct movement away from populated areas;
- Debris basins, or large basins designed to contain the expected debris flow volume;
- Deflection berms intended to direct debris flows away from populated areas;
- Structure elevation and strengthening, designed to locate population above the likely zone of debris flow impacts (Davies, 1997; Hungr and others, 1984; VanDine, 1985);
- Warning systems, including storm warning and/or monitoring of debris torrent travel;
- Avoiding the hazard entirely by either acquiring (and demolishing the structure) or relocating the existing structure away from the hazard area.

In addition, stabilization of the initiating landslide or the debris flow source area(s) has occurred in a few cases.

Debris flow and torrent mitigation strategies suffer from several limitations. It is currently not possible to reliably determine the size of the design debris flow or torrent event (Davies, 1997). Initial cost for most torrent control structures is very high. For example, Sabo dams (check-dams used commonly in Japan) can cost millions of dollars for a simple channel system. Catch-basins must be completely cleaned after debris flow deposition, or will provide little or no protection for the next debris flow event. Channelization, the use of deflection berms, and elevation of the structure will probably be ineffective in areas where the debris torrent is eroding materials, as a debris torrent can rapidly alter channel conditions. There may also be restrictions on channel work because of environmental concerns.

Another mitigation strategy is the temporary closure of roads when debris flows are very likely, or already occurring. The Oregon Highway 38 situation described previously would have been much less likely if traffic had not been stopped below a debris torrent-prone channel. Under ORS 810.030, a road authority may impose restrictions on its own highways as the road authority deems necessary to protect the interest and safety of the general public. Road closure is commonly done for snow avalanches in other states, but not for debris flows. When vehicles are stopped in hazardous locations, the risk is greatly elevated. This is one of the major reasons for the current debris flow warning system, recently installed on Oregon Highway 38, Highway 6, and Interstate 84.

Consistency With Other Natural Resource Regulations as Appropriate

In accordance with Governor Kitzhaber’s Executive Order No. EO 99-01, the Board of Forestry created a Forest Practices Advisory Committee (FPAC). The committee was charged with: (1) determining what, if any, changes to forest practices, both regulatory and voluntary, are necessary to meet water quality standards and to protect and restore salmonids; and (2) making specific recommendations to the Board of Forestry. The committee met for a year and a half beginning in January 1999 and made a series of recommendations. Four of these recommendations deal with landslides, as listed below:

Recommendation O: All landslide-prone locations (now called “high risk sites”) should be identified prior to timber harvest operations. During the notification process, the department should inform the operator of the likely presence of high risk sites in the operation area, based on coarse screen maps. The operator would then be expected to more specifically locate sites within the operation area by field reconnaissance. There is also the expectation that “significant” areas of high risk sites which are not mapped will also be identified by the operator.

Recommendation P: The department should identify stream channels which are prone to debris flows and torrents. Identifying those channels which are capable of transporting large wood to Type F streams could make it possible to focus riparian prescriptions on those streams where greater benefit to aquatic habitats are likely. The department should inform the operator during the notification process of the likely presence of debris flow-prone channels, based on coarse screen maps. The operator would then be expected to more specifically locate debris flow-prone channels by field reconnaissance. ODF would provide specific criteria to be used in field identification.

Recommendation Q: The locations most prone to landslides (now called “high risk sites”) should be managed with techniques that minimize impacts to soil and water resources. To achieve this objective, the best management practices used to protect high risk sites that are currently in guidance should be incorporated into the forest practice rules and a better case history basis for evaluating the effectiveness of those practices should be developed. These standard practices are designed to minimize ground alteration/disturbance on high risk sites from logging practices.

Recommendation R: It is important to leave trees or downed wood in locations where they provide wood to be moved by debris flows into fish-bearing streams. To achieve this objective, it is realistic or appropriate to use a menu of potential methods to leave trees or downed wood, depending upon likelihood of wood delivery and operational efficiency. It is not appropriate to rely on a single strategy to provide this potential source of large wood. The operator should be required to select an appropriate option in cooperation with ODF.

VIII. IDENTIFICATION OF LOCATIONS PRONE TO RAPIDLY MOVING LANDSLIDES

It is necessary to first identify landslide hazard locations if they are to be subject to different management practices, or excluded from management altogether. Hazard mapping can delineate areas of similar or unique (for example, the Tyee Core Area or the Scottsburg Canyon) landslide hazard. To find specific high (and sometimes moderate) risk sites generally requires field work. Once the hazards are identified, it is important to evaluate the natural and human resources that might be affected should the landslide hazard sites fail.

Locations subject to debris flow/torrent impacts are best understood as a path, and not as a single location (Figure 6). The beginning of this path must include steep to very steep slopes. If the path does not include a confined channel (canyon), the debris flow usually stops quickly when it reaches less steep slopes. When the path includes a confined channel, the path can be very long (in rare instances, miles). This path will have variable length and width, depending on the interaction of the many factors described in Sections VI and VII of this issue paper. The tools used to assess this path are generally based on evidence observed on the ground and models based on slope and channel conditions.

Landscape Scale (Maps)

Maps can be developed to help identify areas prone to landslides. Most maps are designed to evaluate landslide initiation hazard (Montgomery and Dietrich, 1994; Hammond and others, 1992). There are some maps that evaluate hazard for the entire debris flow path. For example, the department has mapped debris flow hazard in western Oregon. How precisely maps identify landslide-prone locations depends greatly on the quality and resolution of the data used to develop those maps. Department maps are based on coarse slope steepness information and provide a preliminary indication of debris flow (rapidly moving landslide) hazard for western Oregon.

The Department of Geology and Mineral Industries (DOGAMI) is currently developing "further review area" maps to better identify areas prone to debris flows. This project is using more accurate slope steepness data than was available during the department's mapping efforts. In addition, DOGAMI is working on a model that distributes debris flows down stream channels, and may also model debris fan deposition. These further review area maps are expected to provide a much more consistent and comprehensive screen for locations at risk of impact from rapidly moving landslides.

In general, hazard maps are intended to show areas where further on-the-ground investigation is prudent prior to land management and development activities. They are typically at a coarse scale, so cannot be used to identify specific hazard sites. Specific sites with higher and lower hazards exist in any of the hazard rating categories. Maps are intended as a screening tool and should not be used to determine the actual hazard at any specific location. On-the-ground geotechnical inspections or investigations are required to determine true hazards at any specific site.

Site Scale Identification of Landslide-prone Locations

Debris flows in western Oregon typically begin as small landslides (average 43 feet in length and 24 feet in width (Robison, and others, 1999)). Existing topographic maps (USGS 7.5 minute quadrangles) or digital elevation models (DEMs) based on these maps do not provide accurate landform information for this small size. Therefore, ground-based investigation provides the most reliable information on landslide occurrence and their characteristics in the forests of western Oregon.

The department makes final high risk site designations based on ground measurements of slope steepness, observation of slope concavity, and on location in the Tyee Core Area. Based on storm impacts study data, the department has revised the criteria for determination of high risk sites. The revised criteria would identify between 80 and 90 percent of the landslides inventoried in Robison and others (1999).

High risk sites now include:

a. Any slope (excluding competent rock outcrops) steeper than 80 percent, except in the Tyee Core Area where it is any slope steeper than 75 percent;

b. Headwalls or draws steeper than 70 percent, except in the Tyee Core Area where the headwall or draw slope is steeper than 65 percent; or

c. Portions of landslide-prone terrain determined by a geotechnical specialist and confirmed by ODF to be likely initiation site(s) of rapidly moving landslides (equal or greater hazard than a or b above).

The Tyee Core Area is an area that studies indicate has higher susceptibility to rapidly moving landslides (Robison and others, 1999). It includes thick sandstone beds with few fractures. These sandstones weather rapidly, and concentrate water in the shallow soils, thus the higher landslide hazard. Slopes are typically steep and dissected.

Headwalls are obviously concave-shaped slopes (as seen along the slope contour on the ground surface) that can concentrate water to increase landslide susceptibility. It may be possible to further define headwalls using drainage area per unit length of contour which might be determined in the field.

A few models have been developed to help identify locations prone to shallow-rapid landslides. The SHALSTAB model (Montgomery and Dietrich, 1994) considers both slope steepness and surface drainage area when it calculates a threshold steady-state rainfall calculated to cause slope instability. Therefore, the geographic information used in this model must reliably portray drainage area. Unfortunately, existing topographic maps in steep, forested areas often cannot reliably identify important topography, including concave areas. In addition, water flowing through the rock or through soil piping networks, can be an important component of the water that triggers these landslides (Anderson and others, 1997).

Note also that there is a gradation of hazard across the landscape. Therefore, the meaning of "high hazard" or "high risk" is a relative one. Any single designation of hazard will identify many sites that will not fail, as well as miss many that will fail (Pyles and others, 1998). Therefore, the designation of "high" risk includes both science and policy input. Information on the land area affected by any designation, the number of landslide-prone locations that will not be identified, and the capability of consistent site identification can all help in the selection of appropriate high hazard or high risk criteria. In addition, site scale high hazard site determinations alone cannot determine the risk of damaging debris flows. Debris flow path characteristics are required for such determination.

Debris Torrent-Prone Channels

Davies (1997) states "where a debris flow has occurred in the past, it will occur again in the future; when it will occur is completely unknowable, but it is as likely to be in the near future as in the far distant future." The factors that make stream channels prone to debris torrents include:

- The amount of that channel's watershed prone to shallow-rapid landslides;
- Stream channel gradient (steeper channels are more likely to experience debris torrents);
- Channel confinement (which is needed to keep the debris flow from losing material and momentum in a lateral direction);
- Debris loading in that channel (especially rocks and wood that can be picked up by the debris torrent); and
- The size of the watershed (enough water to cause "flow" behavior, but not so much as to "wash material out").

Historical debris torrent occurrence is an excellent indicator of future debris torrent hazard (VanDine, 1985). Often, this history can be determined from field investigation based on geomorphic evidence around the stream channel.

Gradation of Hazard and Risk

Although the current rules use only one category (high) for evaluation of hazard (and risk), there is, in reality, a gradation of hazards on the landscape, not a clear boundary between locations susceptible to shallow-rapid landslides and locations not susceptible to shallow-rapid landslides.

A moderate hazard for shallow-rapid landslides probably begins at slopes of 40 to 50 percent steepness. Dietrich and Sitar (1997) state that "soil-mantled hillslopes with gradients less than 30 degrees [58 percent], total relief above adjacent channels of less than 90 meters [300 feet] and with well-established brush or forested vegetation can release debris flows capable of destroying homes and killing people."

High risk site rule guidance provides reasonable criteria for high hazard locations. The locations with highest debris flow or torrent hazards exist when these steep slopes are found over most of the watershed, the landscape includes headwall landforms, and there are many steep, confined stream channels. For example, the Rock Hubbard debris flow initiated on one of the less steep slopes within the unit (still, they were steep, 75 percent). Overall, landscape features caused this debris flow to grow into a very dangerous debris torrent.

As with gradation of hazard, there is also a gradation of risk. The specific location of home/road (elevation, distance from path, path characteristics) has a very big influence on the risk to occupants. Relatively small distances can have a big influence on the velocity of the debris flow or torrent, which is probably the most important factor affecting danger to individuals. The highest risk locations are within the actual canyons prone to debris torrents. Fortunately, most of these canyons, at least in Oregon, are too narrow to allow home construction. The Rock Hubbard Canyon was a tragic exception, where the home was located within the canyon itself. Debris fans located at the mouths of canyons are also very dangerous locations, since these fans are typically formed by rapidly moving landslides.

Predictability of Rapidly Moving Landslides

In any given storm, even one of extreme magnitude, only a small percentage of the high risk sites will fail. Davies (1997) concludes that the behavior of debris flows is intrinsically unpredictable, but is not totally random. Therefore, although it is possible to roughly identify those sites that are most likely to fail, it is not possible to assign a time frame to this failure (except in geologic time, hundreds to thousands of years).

Using landslide and debris flow dimensions, the land area directly impacted by slope movement was calculated for the landslides in the ODF study (Robison and others, 1999). For the eight study areas, initial landslide scars accounted for 0.04 percent of the landscape, while 0.15 percent of the landscape was directly impacted by combined landslides plus debris flows. The study area with greatest impact was Elk Creek, where initial landslide scars covered 0.07 percent of the landscape, and debris flow scars covered 0.32 percent of the landscape. These values do not include landslides that did not enter stream channels. In part, this may explain why they are much lower than the 1 to 2 percent typically reported for land area affected by landslides from other studies in the same region (Ice, 1985). Channel effects are far greater than hillslope effects. Thirty-seven percent of stream channels in "red zone" study areas had high (debris torrent-like) impacts in Robison and others (1999). Red zones are areas of the state that, based on aerial reconnaissance after the 1996 storms, had the highest landslide and debris torrent impacts.

Many steep areas are subject to infrequent rapidly moving landslides. On an individual site basis, it is unlikely that any given site will fail in a particular storm. This is true even during the period of increased landslide susceptibility (about ten years after timber harvesting, the actual time probably depending on the speed of regrowth). However, in a landscape context, certain landscapes will eventually fail and result in debris flows. Very large landslides are the most difficult to assess. Unusually large debris flows can impact areas far larger than predicted by available models (Jakob and others, 1997).

IX. FOREST MANAGEMENT CONSIDERATIONS

Timber Harvesting

Silvicultural methods

Silviculture is the theory and practice of controlling forest establishment, composition, and growth (Smith, 1962). Clearcutting typically results in increased landslide occurrence on very steep slopes for some period of time after harvesting. However, except for clearcutting, there is almost no scientific information about other silvicultural harvesting options (partial cutting, for example) and their specific effects on landslide occurrence, at least in terms of specific cause and effect. Research on the efficacy of different silvicultural methods or logging practices is not available (Pyles and others, 1998). Therefore, management decisions for situations where public safety is not at risk are generally based on best professional judgement and include either avoidance of the most hazardous sites or on logical, but often unproven, methods to reduce the hazards, or on some combination of the above.

Storm Impacts Study findings

- Any disturbance that removes vegetation on steep, landslide-prone locations results in increased landslide occurrence. Both the length of time these locations experience periods of reduced forest cover and the extent of lands with reduced vegetative cover can affect landslide density and erosion rate.

- Landscape-level disturbances (large wildfires or major windstorms, for example) can result in large, contiguous areas in a condition susceptible to landslides.

- Alternative management strategies for high risk sites should be carefully monitored. This will take considerable time, since landslides are a geologic process (variable in both time and space). The effectiveness of any specific practices, therefore, will be difficult to evaluate until the landscape has experienced major storms and/or prolonged exposure to geologic processes.

To reduce landslide initiation hazard, forest management techniques on and adjacent to high hazard locations should 1) minimize or eliminate the time period with reduced vegetative cover and 2) not increase the likelihood of trees blowing down. The following landslide mitigation strategies are designed to meet these objectives, to varying degrees (Mills, 1997).

- Not harvesting those locations with the highest landslide hazard will likely prevent the increased landslide occurrence typically observed after harvesting. The background (geologic) hazard remains high.

- To achieve vegetative recovery more quickly, rapid, successful reforestation with older, larger seedlings may shorten the period with reduced vegetative cover after timber harvesting. Note that this may be very difficult on extremely steep slopes with shallow, excessively drained soils, or steep south-facing slopes.

- Higher seedling density may also result in more rapid canopy and root recovery.

- Avoiding high-intensity prescribed fire for site preparation, and not using mechanical site preparation on these sites will reduce soil disturbance and maintain more vegetation.

- Herbicide applications that retard growth, but minimize killing of woody vegetation (if this is possible) can also shorten the period with reduced vegetative cover. If competing vegetation is killed, this is likely to further reduce root strength in the short term.

- For clearcut silviculture, reducing the land area in 0 to 10 year-old stands, and maximizing the land in 31 to 100 year-old stands should reduce the number of shallow-rapid landslides.

- There is no ground-based research or monitoring information on how partial-cut harvesting affects landslide occurrence. Partial cuts should be designed to minimize windthrow hazard. Use of ground-based systems, or construction of roads on steep slopes to facilitate partial cutting may actually increase landslide hazard.

- Leave-areas around high risk sites may be subject to windthrow, as are the boundaries of clearcut harvest units. If leave-areas are too small or if clearcut unit boundaries are located on high risk sites, the landslide hazard could be greater than if those sites were harvested with standard forest practices. Leave-areas should be designed so that windthrow on the high risk site is unlikely.

- Trees left around channels prone to debris torrent scour, or wood that falls in or is placed in these channels may be recruited as large wood in these debris torrents. Such wood may have beneficial value for aquatic habitat, but may also make debris flows more hazardous to people.

Headwall leave-areas

The headwall leave-area technique is recommended by Forest Ecosystem Management Assessment Team (FEMAT) (1993) for federal forestlands based on a study by Swanson and Roach (1987). Specifically, FEMAT recommended that leave-areas of about three acres in steep headwall areas be protected from timber harvesting. Due to the small amount of harvesting on federal lands, and the fact that many headwall leave-areas overlap with areas receiving riparian protection near seasonal streams, there is little information available to evaluate the effectiveness of the headwall leave-area technique. Anecdotal evidence from Swanson and Roach (1987) and Martin (1997) indicate that small headwall leave-areas may increase the risk of windthrow, and therefore probably increase landslide occurrence as well.

Logging practices

Felling and yarding practices on high risk sites are currently designed to 1) minimize ground disturbances, 2) prevent physical steepening of slopes, 3) prevent directing drainage waters to high risk sites and 4) avoid slash accumulations in channels prone to debris flows. However, these practices have little or no effect on root or canopy growth after timber harvesting and their effectiveness is unknown. Specifically, the following practices are currently being used to minimize ground disturbance:

- Skid roads are not excavated on high risk sites.
- Cable yarding systems are laid out to eliminate gouging (log dragging) and reduce other ground disturbance on high risk sites.
- Trees are fallen so that they do not roll or slide into high risk sites.
- Landing-fill is not placed on high risk sites or other steep slopes.
- Landing-slash on or above high risk sites or other steep slopes is physically removed or consumed by fire.
- Landing drainage is not directed towards high risk sites.

Stream Channel Protection Practices

Under current rules, slash accumulations are to be removed from debris flow-prone channels as needed to protect stream habitat and water quality. Logging-slash, natural large wood, and even standing riparian vegetation can be incorporated into a rapidly moving debris torrent, possibly making the debris torrent larger and more destructive. Boulders and other debris associated with road construction can also add to debris loading if they end up in channels (VanDine, 1985).

Storm Impacts Study findings

- More slash was found in stream channels within recent harvest units as compared to channels that flowed through mature forests. However, whether these differences in slash resulted in increased travel distances by debris torrents could not be determined.
- The debris torrents that traveled further than predicted were, on average, larger and had younger riparian vegetation near their terminus, indicating that landslide volume and composition of the riparian area along debris torrent-prone channels may be important secondary factors in determining landslide run-out distances.
- Based on these conclusions, when evaluating debris flow or torrent risks to resources based on potential run-out, one should consider the potential for large, initiating landslides as well as channel junction angles, stream, and the riparian condition along the debris flow/torrent path channel gradients.

Road Location, Construction, and Maintenance Practices

In the early 1980s, the Board reviewed the existing rules and administrative processes related to landslide prevention and substantively modified how forest roads are designed and constructed on steep slopes and high risk sites. Written plans are now required as necessary for roads crossing high risk sites and other steep slopes.

For slopes that are considered at high risk for landslide potential, a technique known as end-hauling is used to transport excess excavated materials to more stable waste area locations (this is required in Oregon). Using steeper grades to keep roads on ridgetops can be a significantly less expensive road system design compared to having to end-haul for steep slopes. Relocating roads in lower-risk areas is also an effective means of landslide prevention. However, where these practices are not possible, end-hauling may be an effective, albeit expensive, technique for reducing landslide occurrence (Sessions, and others, 1987).

Storm Impacts Study finding

Based on the relatively low numbers of road-associated landslides surveyed in this study and on the smaller sizes of these landslides (as compared with previous studies), current road management practices are almost certainly reducing the size of road-associated landslides, as well as the number of landslides.

Roads versus timber harvesting

Roads result in a more permanent increase in landslide hazard than does timber harvesting. End-haul construction and closely spaced cross-drainage structures can greatly reduce, but not eliminate, the increased hazard. On a high risk site, a forest road constructed using the best possible construction practices probably still poses an increased landslide hazard which, based on professional judgment, is probably greater than the hazard associated with vegetation removal on that site.

X. OTHER ACTIONS TO PROTECT OREGONIANS FROM RAPIDLY MOVING LANDSLIDES

In the issue paper for the Task Force on Landslides and Public Safety, the department stated that "the most certain way to avoid public safety threats from fast moving debris flows is to keep people out of precarious locations, especially during extreme rainfall periods" (ODF, 1998). Based upon our review of all available information, this still appears to be true. Forest management activities on steep slopes above homes and roads can increase risk to people in these locations. However, forest practices regulations are only one part of an overall risk reduction strategy. Alone, forest practices regulations can do little to reduce exposure of people to long-term rapidly moving landslide threats. Many actions have been taken to better inform Oregonians of these hazards, and to help them stay out of dangerous locations. However, the level of awareness still appears to be low in some cases.

A broader context view of the current situation was described by Eisbacher and Clague (1986). "Rapid expansion of tourism and hydroelectric developments throughout many mountain regions of the world are proceeding within a social context different from that of pioneer communities: self-reliance of pioneer communities necessarily included acceptance of high levels of natural, self-inflicted risks. In contrast, the modern consumer commonly expects to be protected from hazards, at least from those created by human activities. Whether such protection should be extended to naturally occurring mass movements is problematic. On the one hand, strict hazard zoning prior to development is highly unpopular with developers and individuals who feel such measures interfere with their freedom of choice. On the other hand, the same citizens often tend to blame inadequate government involvement after destructive mass movements have occurred. A balance between these two attitudes has to be achieved."

Education/Hazard and Risk Awareness

Oregon experienced relatively dry winters between 1983 and 1996. There were few debris flows during this time period, so there was little to make people aware of this hazard. Existing landslide maps typically had been focused on "on-site" landslide hazards, not on landslides that move long distances from steep slopes. Since 1996 and the Governor's Plan, this awareness has increased somewhat. Still, debris flow and torrent events do not make the news very often, especially if there is not a big story involved. For example, the debris flows that killed two loggers on the border of Lane and Douglas Counties in February 1999, and another in Mapleton that severely injured a resident during the Thanksgiving 1999 storm both resulted in little media attention.

A brochure titled "Landslides in Oregon: Protect Yourself and Your Property" was developed in 1997. Technical guidance for geotechnical investigations in debris flow-prone areas is now being developed. However, it is apparent that many Oregonians, including land-use officials, still do not understand the dangers associated with debris flows and torrents. Improving their understanding can do a lot to further reduce risks to Oregonians.

Over the past year, department field personnel have identified at least two situations where dwelling sites were being developed on dangerous debris fans. In both situations, the landowners obtained county approval for development. The department had notified these counties of debris flow hazard maps being available. However, this effort was apparently unsuccessful, at least in these two situations. The department has worked with Douglas County to evaluate a proposed home site on a debris fan before building site approval. The landowner in this case was unsuccessful in securing a permit, and was very upset with this decision. More consistent intergovernmental coordination is needed to ensure that new homes are not sited on these dangerous locations.

Debris Flow Warning System

To be most useful, warnings would be issued before each debris flow-producing storm, giving residents and highway departments enough time to take actions. There are a number of factors that make this difficult. Seemingly insignificant factors, such as trees blowing down, soil piping, or animals burrowing in the ground may change the flow of water in slopes. This can make certain sites vulnerable to debris flows at rainfall levels below normal thresholds. Human activities - particularly roads, excavations for building sites, timber harvesting and certain other land-clearing operations – can also make a location more susceptible. Each new storm event adds to the department's information base and aids technical staff in refining criteria for forecasting debris flows. Like other new technologies, the system should improve over time.

Warnings and advisories are intended to identify the time frame and general area where debris flows are expected and cautions the public to avoid high risk locations within the described area. For some, this may involve immediate evacuation of a home located in a potential debris flow channel. For others, the response could be as simple as choosing an alternate travel route to steer clear of a hazardous highway segment. At the present time, however, people who are in dangerous locations are often not aware this is the case, so may not effectively use the warning information. Therefore, the issuance of more advisories is planned, along with more media coordination. Warnings will be reserved for extreme events only

Land-Use Goal 7 - Natural Hazards

Goal 7 *"to protect property from natural disasters and hazards"* is one of Oregon's 19 Statewide Planning Goals. Developments are not to be *"planned nor located in areas of known natural disasters and hazards without appropriate safeguards."* The word "known" has been a concern, since many hazards have not been mapped, and local governments do not always appear to be eager to obtain this information. Therefore, the Department of Land Conservation and Development (DLCD) is updating Goal 7 so that local governments more actively identify natural hazard areas.

An example of local governments not actively seeking hazard information occurred as the department completed its debris flow hazard maps. A letter was sent to all local governments found to have moderate, high, or extreme debris flow hazards mapped near or within their jurisdictions advising the local governments how they could get maps from the department. However, only about one-third of the local governments responded with questions about how to obtain and use these maps (see Education/Hazard and Risk Awareness).

DLCD has completed natural hazard technical resource guides for local governments, one of which deals with landslides. The department assisted in development of the landslide guide, which should provide very useful information to local governments.

Road Management

As called for by Senate Bill 12, ODOT has taken actions to provide warnings to motorists during periods determined to be at highest risk of rapidly moving landslides along areas on state highways with a history of being most vulnerable to rapidly moving landslides. To assist this effort, ODF identified three segments of state highways of highest concern for landslide vulnerability. In order of concern, they are:

1. Oregon 38 (Umpqua Highway) – milepost 6.5 to milepost 17
2. Interstate 84 (Columbia River Highway) – milepost 20 to milepost 40
3. Oregon 6 (Wilson River Highway) – milepost 5 to milepost 35

ODOT is installing warning signs at each end of the segments of highway identified by ODF. The signs have yellow flashing lights and read "POSSIBLE LANDSLIDES NEXT XX MILES WHEN LIGHTS FLASH." Upon notification that ODF has issued a debris flow warning, the appropriate ODOT dispatch center will activate the flashing lights. The flashing lights will remain activated until ODOT is notified that ODF has cancelled the warning.

The Department of Forestry has concerns with this message. Given the conservative criteria used to issue a warning, dangerous landslides are likely (not just possible) during a warning period. Warnings are rare. No warning has been issued since the warning system was developed. Debris flows are possible during an advisory period (and for these highways, experience has shown that they can occur under even advisory thresholds). Note also that advisories are also uncommon (0 to 2 per year for last 3 years). The department has recommended to ODOT that they reconsider their strategy, since it may not provide motorists with information of the potential gravity of the hazard.

Homeowner Acceptance/Personal Management of Risk

Property owners in steep rural areas have already accepted increased risks by living in areas with relatively high rapidly moving landslide hazards. Some landowners have requested accepting any risks associated with harvesting timber or road building on their own property. While the rights of the property owner are very important, the threat to children or others who might be in the house and who have not been part of the decision to accept these risks is also of serious concern. This is especially true if the property is sold to an individual who does not fully understand the dangers involved, or if minors live in this location.

Under the interim prohibition of operations, the department does not consider the fact that the homeowner and timber owner may be the same. Several homeowners have thus been affected by the interim prohibition of forest operations. On the other hand, Sub-section (4)(3) of Senate Bill 12 prevents forest practices public safety regulations from applying to homes constructed after 1999. Residents of new homes are expected to accept and manage their own risk.

Voluntary Property Acquisition and/or Relocation

Many properties impacted by the widespread flooding and landslides resulting from the storms of 1996 had historically experienced similar damage. Properties with such a history of landslide damage are good candidates for mitigation that works to avoid the hazard, rather than control the hazard. Projects using mitigation funding can acquire landslide damaged or threatened homes to minimize the possibility that landslide-related damages could ever occur in that location again.

Forest Road Hazard and Risk Reduction Project

Voluntary measures have been developed in conjunction with the Oregon Plan for Salmon and Watersheds. One such voluntary measure is aimed at inventorying pre-existing road hazards and taking action to repair these older roads. In the case of roads on steep slopes not meeting current design standards, this means reducing the threat of landslides by removing sidecast material, adding new drainage structures, and by stabilizing and vacating roads that are no longer needed. A failure of an old road near Alsea in 1998 resulted in a debris flow that almost killed two occupants of a home along the debris flow path. This road had been slated for repair under the Oregon plan, but those repairs had not yet been completed.

XI. POLICY CONSIDERATIONS

A project team is considering the nine issues raised on page one of this issue paper. To help the team in this effort, seven policy considerations have been identified for review and discussion by the project team. Alternatives and recommendations will be based on project team input, the requirements of Senate Bill 12, and the guiding principles. More specific rule concepts will also be developed in collaboration with the project team and the forest practices regional committees. Input from potentially affected parties will be solicited and incorporated into the rule concepts.

1. Keith Mills, ODF, Salem, Team Leader
2. Dr. Arne Skaugset, Oregon State University
3. Dr. Scott Burns, Portland State University
4. Dr. George Ice, National Council for Air and Stream Improvement, Corvallis (NCASI)
5. Tally Patton, Boise Cascade, Monmouth, Northwest Regional Forest Practices Committee
6. Jim Clarke, Weyerhaeuser, North Bend, Southwest Regional Forest Practices Committee
7. Sara Leiman, Monroe, Coast Range Conifers, Oregon Small Woodlands Association (OSWA)
8. Penny Lind, Umpqua Watersheds, Roseburg
9. Marilyn Heiken, Johnson, Clifton, Larson and Corson, P.C., Eugene
10. Matt Spangler, Lincoln County Planning Department
11. Wayne Stinson, Douglas County Emergency Manager
12. Dennis Olmstead, Department of Geology and Mineral Industries, Portland
13. Ann Beier, Department of Land Conservation and Development, Salem
14. Rose Gentry, Department of Transportation, Salem
15. Dennis Sigrist, Office of Emergency Management, Salem
16. Jon Hofmeister, Department of Geology and Mineral Industries, Portland

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Specific Policy Considerations

1. It is important to consider hazard and risk separately for identification of locations prone to initiation or impact from rapidly moving landslides.

This has become much more important since public safety and natural resource risks are very different. This policy would likely result in some differences in appropriate forest management activities on both landslide-prone sites and also around debris flow-prone channels. And although it is not possible to predict the specific occurrence of rapidly moving landslides, it is possible to characterize where they can occur and where, if they do occur, they will pose a significant threat of serious bodily injury or death.

2. Using the same general site identification criteria for public safety as for natural resources should reduce rule complexity and allow more consistent rule application.

The same locations are subject to shallow-rapid landslides, and the same channels are prone to debris flows, so the means to identify these channels can be the same. It may, however, be necessary to better identify the highest debris flow hazard locations (those where debris torrents are likely to be more frequent and more destructive). For example, the debris torrents that caused the 5 fatalities in 1996 all occurred in terrain mapped as extreme hazard on the department's debris flow hazard maps (these maps completed after the 1996 debris torrents). These areas are of fairly limited extent, and contain more steep slopes and confined stream channels than most parts of Oregon.

3. Developing rule concepts that are scaled by risk is required by law and the guiding principles.

Section 12 of Senate Bill 12 includes the following requirement. "The rules shall consider the exposure of the public to these safety risks and shall include appropriate practices designed to reduce the occurrence, timing, or effects of rapidly moving landslides." As per Guiding Principle #3, operations on slopes that pose the greatest risk to people should be subject to the most restrictive regulations. This includes both the inherent hazard related to site and channel characteristics, the location of the population, and how likely people will be in dangerous locations when rapidly moving landslides are likely. One outcome of this would be to use practices for operations above homes that are different from practices used for operations above highways, and also different practices for non-channelized debris flows as compared to debris torrents.

4. Evaluating the "window of vulnerability" or silvicultural alternatives is one means to develop practices that are scaled by risk.

There is no applied scientific research on the effects of different forest management activities on the occurrence of shallow-rapid landslides. A "Silviculture Team" was formed and used existing scientific information and best professional judgments to evaluate the relationship between silviculture and landslide initiation. This team includes the following representatives:

Dave Michael, ODF Northwest Area Geotechnical Specialist, team leader
Dr. Arne Skaugset, Forest Hydrologist - Geotechnical Specialist, Oregon State University
Tally Patton, Boise Cascade, Monmouth, Northwest Regional Forest Practices Committee
Andy Stahl, Executive Director, Forest Service Employees for Environmental Ethics
Dr. John Tappeiner, Silviculture Expert, Forest Resources Department, Oregon State University

Based on team discussions and a comprehensive literature review, a "Silviculture and Landslides Susceptibility" report was drafted (Appendix 3).

5. Practices that reduce potential debris loading in channels prone to debris torrents above homes and roads can reduce the impacts from rapidly moving landslides.

Practices that provide large amounts of wood of any size to channels are likely to increase the size of debris torrents. For public safety, therefore, practices would be designed to reduce wood loading in streams channels. This is very different from the practices that would be appropriate for natural resource protection, as reducing wood loading will be detrimental to the needs of aquatic life. Therefore, the Board will have to make a policy decision on if, and how, to balance the biologic needs and the public safety needs.

6. Completed mitigation projects (in the channel or around the home) should be considered in determination of necessary forest practices regulations, since they can, in some cases, more efficiently provide public protection.

Guiding Principle #5 states "Where protection of public safety can be achieved more efficiently through means other than forest practice regulation, the department should facilitate these measures, as resources permit." Forest landowners have already proposed to the department that they could work with homeowners to construct debris torrent mitigation projects around homes. The current interim prohibition of operations criteria do not, however, consider mitigation strategies. Strategies including deflection berms, settling basins, and moving structures may work in many cases, especially when the property is not in a confined canyon, or on a debris fan. Such mitigation can reduce, but generally not eliminate, risk from rapidly moving landslides. Note that most debris flow mitigation measures were not designed for large wood (debris torrents).

7. It is important to include in the rules objectives a statement to the effect that landslides will continue to occur despite any forest practices regulations.

No matter what regulations are adopted, persons in debris torrent-prone areas will still be at risk of serious injury or death. The best that forest practices regulations can do is to reduce the risks of forest operation influenced landslides. Therefore, regulations should be very explicit in explaining that rapidly moving landslides will occur despite any restrictions on forest management activities. Landslides will occur on forestlands, and cause public injury. Therefore, the Department of Justice should help draft language that will reduce agency legal liability when landslides do occur in these areas.

XII. STRATEGIES AND ALTERNATIVES

The Project Team considered a range of regulatory and non-regulatory alternatives. The Project Team addressed forest practices, building development, road management and emergency management issues. Many alternatives were considered. After team discussion, a number of alternatives were deemed technically unsupportable by the project team. As per team agreement, unsupported alternatives have been dropped from consideration. The reader may notice gaps in the numbering of alternatives. These gaps represent technically unsupported alternatives.

Forest practice regulations can be one element of a strategy to protect Oregonians from rapidly moving landslides. Forest management activities may affect the timing and the magnitude of rapidly moving landslides. By themselves, however, forest practice regulations do nothing to affect the inherent (geologic) hazards associated with rapidly moving landslides. Therefore, if forest practices regulations are to be effective, they must be incorporated with strategies to reduce the population in hazardous locations during major storm periods.

Based on Task Force on Landslide and Public Safety member discussions, task force members had an understanding that there would not be a one-size-fits-all strategy for forest practices regulations. They felt that strict avoidance of all forest activities was only warranted in the most extreme situations.

Reducing the number of dwellings in the most hazardous locations should have the greatest public safety benefit. Dwellings might be moved to a safer location, or removed. Forest landowners have been working with willing homeowners to acquire homes in dangerous locations below their forestlands. Other options that have not yet been considered include: structure elevation, debris torrent diversion berms, and catch-basins. For roads, it is essential to give motorists better information on debris flow hazards, and to close highways before traffic backs up behind debris flows.

The following four strategies are designed to deal with the issues raised at the beginning of the issue paper.

<u>Four Strategies</u>

I. Developing risk-based forest practices regulations. This strategy includes the following sub-strategies:
A) Screening of operations that may have landslides/public safety effects.
B) On-the-ground identification of high hazard landslide-prone (initiation) locations within proposed operations.
C) Evaluating rapidly moving landslide hazard for screened operations.
D) Requiring forest practices that maintain and/or rapidly recover root strength and canopy and that reduce or prevent road-associated landslides on high (landslide initiation) hazard locations with high public safety risk downslope.

E) Using debris flow path management practices that reduce debris loading and/or reduce debris flow travel distance.

II. Improving residents' ability to recognize where and when they might be at risk from rapidly moving landslides and how they can protect themselves.

III. Providing physical mitigation between high hazard sites, homes, or roads.

IV. Reducing the number of dwellings, and during extreme rainfall periods, vehicles in locations prone to rapidly moving landslide impact, since regardless of management, there is high hazard in these locations. This strategy is designed to reduce the conflicts between forest management and persons in vulnerable locations.

Strategy I. Developing risk-based forest practices regulations.

Strategy I will:
- Direct costly mitigation where it will have the greatest benefit.
- Reduce economic effects on landowners.

This strategy is the forest practices regulatory portion of the rapidly moving landslide issue. It will be used to determine where public safety regulations are needed, and what level of regulation is appropriate. The first element of this strategy is evaluating potential public exposure to rapidly moving landslides.

ALTERNATIVES FOR CONSIDERING EXPOSURE AND HAZARD TOGETHER (RISK)

I.1) Utilize exposure categories for potential impacts from rapidly moving landslides. The three exposure categories for consideration are based on the relative likelihood of a person being present at any given time.

Exposure Category a. Habitable residences, schools, commercial or public offices.

Exposure Category b. Roads with over 500 vehicles per day (as determined during winter months if possible).

Exposure Category c. Barns, outbuildings, recreational dwellings, public roads with 100-500 vehicles per day.

Exposure Category a includes those situations where people are most likely to be present. People are typically present in year-round residences more than 50 percent of the time. Schools and commercial or public offices may be occupied less frequently (25 percent of the time), but typically contain more occupants than a home. Vehicles, even on very busy roads (Exposure Category b), are at reduced exposure from rapidly moving landslide impact. Finally, barns, outbuildings, recreational dwellings (fishing shacks, remote cabins, etc.) and public roads with

100-500 vehicles per day (Category c) are unlikely to be occupied during periods when debris torrents occur. However, people could still be present in these locations.

The alternatives for exposure categories include modification of those conditions falling into each category, and either including, modifying or eliminating Exposure Categories b and c. In addition, the alternative selected should be worded to ensure that the Board of Forestry makes the final policy decision.

The following alternatives are based on both exposure of persons and on the likelihood of rapidly moving landslide impact. Risk is equal to the exposure multiplied by the hazard (likelihood of impact from rapidly moving landslides). When persons are at highest exposure, and the hazard of a rapidly moving landslide is greatest, avoiding forest operations may be the most appropriate practice to reduce risk. For lower (but still significant) levels of risk, intermediate forest practices are consistent with a risk-based forest practices strategy. Finally, when the risk to people is low, standard forest practices for natural resources may be appropriate. The following tables help explain these alternatives (there are many possible combinations). Specific alternatives for appropriate forest practices are discussed in sub-strategies D and E. The hazard rating points would be based on the alternatives selected in sub-strategy C.

I.2) Restriction levels for operations where persons are at greatest exposure to rapidly moving landslides (Exposure Category a).

Forest Practices for Exposure Category a	
Hazard Rating Points	Appropriate Forest Practices
under x (low)	natural resource protection
Typically locations away from the mouth of canyons, or elevated above the potential debris torrent	
x to y (moderate)	intermediate
Typically locations on debris fans with sharp channel junctions between operation and home/road, or below uniform steep slopes with no debris fans	
over y (high)	no road or harvest
Typically locations in canyons or on debris fans with no sharp channel junctions	

I.3) Restriction levels for operations where persons are at intermediate exposure to rapidly moving landslides and where exposure can be controlled (highways) (Exposure Category b).

The Board of Forestry (BOF) will need to make a policy choice for roads, since road access may be controlled. The Board may or may not choose to apply additional forest practices above highways. Since Highway 38 has a long history of rapidly moving landslides due to extreme hazard, this highway may be considered differently than other highways. Should the BOF choose not to apply regulation beyond natural resource practices to roads, Exposure Category b will be dropped.

Forest Practices for Exposure Category b	
Hazard Rating Points	Appropriate Forest Practices
under y (low to moderate)	natural resource protection
Typically locations below steep slopes with no channel or debris fan	
over y (high)	intermediate
Typically locations on debris fans, sharp channel junctions between operation and home/road	

I.4) Restriction levels for operations where persons are at lower exposure to rapidly moving landslides (Category c). In most cases, these would be subject to standard natural resource protection. There may be cases, however, where a higher level of protection is appropriate.

Sub-Strategy I.A: Screening of operations that may have landslides/public safety effects.

Sub-Strategy I.A is important because:
- It identifies operations where special forest management activities may be required.
- It can provide other land users (homeowners and road managers, for example) with information on rapidly moving landslide hazards.

The alternative(s) selected under this sub-strategy should help the department, landowners and operators identify rapidly moving landslide initiation sites, rapidly moving landslide paths, and the locations where people might be at risk (homes and highways). The following alternative screening tools are not necessarily exclusive, and it may be necessary to select more than one alternative for this sub-strategy.

TOOLS TO SCREEN FOR HIGH HAZARD LOCATIONS WITHIN OPERATIONS AND IDENTIFY STRUCTURES OR ROADS THAT MIGHT BE AFFECTED BY RAPIDLY MOVING LANDSLIDES INITIATING WITHIN FOREST OPERATIONS

I.A.1 Identification of high hazard locations

I.A.1-3 Further Review Area Maps are the maps required by Senate Bill 12. DOGAMI should be finished with final model development for these maps shortly. This model will show the entire path of the rapidly moving landslide, and the expected debris fan impact location.

The project team also considered other alternatives including the department's debris flow hazard maps, slope steepness maps, and other models. However, these other tools all have significant limitations, and the team agreed by consensus that only the further review area maps are appropriate.

I.A.2 Identification of population at risk

I.A.2-1 A map or other inventory tool that accurately identifies the locations of homes and highways and busy roads would reduce the need for field evaluations of large areas below high hazard locations. Some counties already have GIS maps of residential addresses. However, these addresses may be the mailbox location rather than the actual home. USGS topographic maps typically show structures (indicated by black squares).

I.A.2-2 ODF experience, including volunteered information from residents and operators, can be used to identify homes near locations prone to rapidly moving landslides. Forest practices foresters are currently using their personal experiences to conduct the screening of operations subject to the interim prohibition of operations. Information from residents in high hazard communities would be welcome, but would not be relied upon as a final source of screening information.

I.A.2-3 Operators would provide information on neighboring homes on the notification of operations form. This could be a rule requirement for any operation within a mapped further review area.

Sub-Strategy I.B. On-the-ground identification of high hazard landslide-prone (initiation) locations within proposed operations.

Sub-Strategy I.B is necessary because:

- It will verify the need for special forest management activities.
- It focuses specific timber harvesting and road construction restrictions in specific locations where they might affect public safety.
- It allows for consistent identification of locations with similar landslide initiation hazards.

For sites where slopes are near the threshold criteria, high risk sites are currently based on field-based identification (rather than map-based) since maps do not provide accurate slope steepness and landform information (see the current high risk site criteria on page 45). The current criteria is designed for use by non-geoscience professionals (i.e. foresters), although geotechnical specialists can be used to better identify locations that are near the threshold hazard criteria, or have unusual features. The existing terminology "high risk site" is misleading, since risk depends on downslope conditions (the presence of people or natural resources). In addition, the word "location" is probably better than "site," since they may encompass very different sized areas, and typically do not have precise boundaries.

ALTERNATIVES FOR IDENTIFICATION OF HIGH HAZARD LOCATIONS

I.B.1 Place the current ODF criteria for site identification into rule form, as recommended by the Forest Practices Advisory Committee (FPAC). These locations would be identified as "high hazard locations" not "high risk sites," since risk depends on conditions along the debris flow/torrent path and on exposure of persons or natural resources. ODF will screen and notify landowners about high hazard locations. Landowners will then be responsible for describing the high hazard locations in the written plan. Landowners and operators would also be expected to find easily identifiable locations on the ground, even if the ODF screen did not identify these locations.

The team considered other alternatives for identification of high hazard locations, including higher and lower hazard thresholds, and the use of geoscience professionals to make these determinations. However, no other alternatives received team member support, so they have been dropped from this issue paper.

Sub-Strategy I.C. Evaluation of rapidly moving landslide hazard.

Sub-Strategy I.C is necessary because:
- It provides information to save lives.
- It allows applications of specific practices to reduce risk.
- It can foster shared responsibility.

There are many factors that affect the severity of risk from rapidly moving landslides. An evaluation of risk is an essential part of risk-based regulations (all elements of Strategy 1). However, risk analysis procedures for any given location are not yet developed. The department is currently conducting the "debris flow impacts study" to better address this issue (Appendix 4). Whatever alternative is selected, careful monitoring will be needed. To avoid confusion, it is important to select one alternative for sub-strategy I.C. However, this alternative may be a combination of the current alternatives shown below.

ALTERNATIVES FOR EVALUATION OF RAPIDLY MOVING LANDSLIDE HAZARD

I.C.1 The level of hazard would be based on information from the debris flow impacts study, looking at the precise location of the populated site. Hazard factors would be assigned a point value. The higher the total points, the greater the hazard. The principal hazard factors are physical parameters in the debris flow path, and might include: acreage of high hazard in debris flow shed; channel junction angles; channel confinement; channel gradient; channel debris; angle of reach; and location of population (in-canyon, top of fan, on fan, off center of fan, open slope).

I.C.2 The level of hazard would be based on the output from a model with follow-up fieldwork used to validate the output from the model. DOGAMI is currently using a model developed by the Earth Systems Institute to conduct the further review area mapping.

I.C.3 The level of hazard would be based on the professional judgement of a geoscience professional. Fieldwork by that professional would be required. Training for consistency would be essential. It may also be necessary to develop different certifications for these professionals.

Sub-Strategy I.D. Requiring forest practices that maintain and rapidly recover root strength and canopy on high (landslide initiation) hazard locations with high public safety risk downslope.

Sub-Strategy I.D should:
- Provide a marginal level of increased public protection as compared to natural resource protection practices.
- Balance increased public protection with allowing forest landowners economic benefit from as much of their lands as possible.
- Reduce or eliminate the window of vulnerability to rapidly moving landslides caused by certain forest operations.

The appropriate alternatives depend on the specific public safety risk. Therefore, two sets of alternatives are appropriate. Where public safety risk is greatest, prohibition of operations on the most hazardous locations can be appropriate. However, there are many cases with intermediate public safety risk. For these intermediate risk situations, additional management options may be appropriate. However, it is important to note that most of these intermediate management options have not been tested for efficacy. Multiple alternatives are probably appropriate for sub-strategy I.D.

ALTERNATIVES FOR HIGHEST RISK SCENARIOS

I.D.1 Not harvesting on the high hazard locations. This alternative will prevent the increased landslide occurrence usually observed after harvesting very steep slopes. It does nothing to affect the inherent geologic hazard at these locations. Removal of trees, generally dead, could be allowed if no increase in landslide hazard can be demonstrated (certain wildfire and landslide salvage operations).

I.D.2 No road construction in the high hazard locations, since roads typically result in a greater hazard increase than timber harvesting. Road reconstruction that lowered the hazard could be permitted (this would be a rare occurrence).

ALTERNATIVES FOR INTERMEDIATE RISK SCENARIOS

I.D.3 Silvicultural practices that limit the high hazard area (acreage) in vulnerable condition (by landowner or operation) may result in a limited increase in hazard (and therefore also in risk to persons). For example, a home may have four 15-acre high hazard headwall basins on the hillslopes above it. Removing the trees on one of these basins would be expected to result in an increased risk, but one that is one-fourth the increase of harvesting all the high hazard headwall basins, all other things being equal. This alternative is not harvest scheduling (at least not by the State), since plans would continue to be reviewed on an operation-by-operation basis. Landowners would evaluate their land-ownership above homes, and would provide a written plan to the department showing that only a limited portion of high hazard locations on their properties would be in a vulnerable condition (based on vegetative cover). In addition, the locations with the highest hazard would be preferentially selected for no harvesting.

I.D.4 Practices to ensure more rapid canopy and root recovery and that are intended to reduce the length of time (years) where increased landslide occurrence is expected. This alternative is theoretically sound but has not been field-tested. This alternative will probably require more rapid and effective reforestation with large seedlings and/or more seedlings than under current rules. Different herbicide application and slash burning practices might also be needed. Note that current reforestation requirements are more aggressive than those in place ten years ago.

I.D.5 Practices to ensure less loss of canopy and roots and that are intended to reduce the increase in landslide occurrence (to less than twice other stand ages). This alternative is theoretically sound but has not been field-tested. This alternative includes thinning or partial cutting younger forests and at a level where canopy and root recovery occur quickly.

I.D.6 Special steep land road construction practices that result in lower risk than current full bench end-haul practices. This alternative has not been completely tested. The road design would be designed by a geotechnical specialist to reduce likelihood of cutslope failures diverting drainage to high hazard locations.

I.D.7 Additional design and review for forest road construction operations that might result in large, rapidly moving landslides. There have been cases where road fills in steep stream channels and waste disposal areas have triggered large landslides. Therefore, additional review is appropriate in these limited situations.

Sub-Strategy I.E. Using debris flow path management practices that reduce debris loading and/or reduce debris flow travel distance.

Sub-Strategy I.E is critical because:

- Additional debris along the debris flow path can make debris torrents more dangerous.
- Wood may provide benefits for fish and aquatic habitat but, in many cases, may not provide benefits for public safety.
- Large standing trees near the terminus of debris flows/torrents may serve to arrest debris torrent movement.

Conditions in the debris flow path may be as important as conditions at the landslide initiation site in terms of affecting risk to people in vulnerable locations. In general, debris in streams can be expected to increase risk to people, or at a minimum, make behavior of a debris torrent more unpredictable. These practices are intended for operations where the public safety risk assessment indicates practices in excess of natural resource protection are appropriate. Multiple alternatives may be selected for sub-strategy I.E.

DEBRIS FLOW PATH MANAGEMENT ALTERNATIVES

I.E.1 Fall and yard trees to minimize slash and other debris accumulations associated with the operation in debris torrent-prone channels and hollows, since this debris may increase risk to people.

I.E.2 Remove slash accumulations (multiple chunks that can be moved by choker) that have entered debris torrent-prone channels and hollows and place this material in locations where it is unlikely to be carried by rapidly moving landslides, since these slash accumulations may increase risk to people.

I.E.3 Leaving larger trees standing next to the lower (6 to something less than 20 percent) gradient part of debris torrent-prone channels. This practice may reduce the velocity of a debris torrent, causing it to travel a reduced distance. This practice already applies to Type F channels, but would be a new requirement for some Type N channels. House Bill 2163, currently awaiting the Governor's signature, may provide additional trees in some cases as well. This alternative may have a possible mitigation value (see Strategy III). This is a relatively untested alternative. In some cases, large debris torrents may incorporate standing trees into the flow, increasing public safety hazard.

Strategy II. Improving residents' ability to recognize where and when they might be at risk from rapidly moving landslides and how they can protect themselves.

Strategy II. Warnings and evacuations should:
- Target those persons at greatest risk.
- Identify specific time frames and locations when rapidly moving landslides are most likely.
- Minimize "cry wolf" warnings and advisories.
- Be a shared responsibility.

This is a very important strategy, since the population living and driving through locations prone to rapidly moving landslides is significant. However, homes in these locations are generally widely spaced, so local government has little or no ability to facilitate evacuations. Therefore, local communities and individual residents must take on this responsibility. Multiple alternatives may be selected for Strategy II.

ALTERNATIVES TO IMPROVE RESIDENTS' ABILITY TO RECOGNIZE WHERE AND WHEN THEY MIGHT BE AT RISK FROM RAPIDLY MOVING LANDSLIDES AND HOW THEY CAN PROTECT THEMSELVES

II.1) Develop more detailed information (brochure type) for homeowners living in debris flow-prone locations. This would include: a simplified means to assess risk at their home site; services provided by geoscience professionals; the effects of vegetation removal; and how to manage risk using warnings and developing an evacuation plan. The department would lead this effort, with input from DOGAMI, emergency managers, certified engineering geologists, and registered professional engineers specializing in geotechnical engineering.

II.2) Preparatory to storm events, notify residents in locations prone to rapidly moving landslides of their circumstances so that they can take steps to protect themselves. These steps might include: an evacuation plan, mitigation around the house, moving the structure, or selling the property to another landowner, and/or developing a phone tree to communicate warning information. There has been some success in identifying homes subject to other hazards (for example, homes in the urban wildfire interface). This information would be directed to persons living in further review areas as mapped by DOGAMI. This action should be taken by state or local government.

II.3) Make significant improvements to the current warning system. Currently, radar sites do not allow good resolution of storms in the Coast Range, since the existing radar sites near Portland and Medford are a long distance from the most landslide-prone terrain, and are blocked to some degree by the Coast Range Mountains. Changes could include a new Doppler radar station in the central Coast Range, and five to ten automatic real time rain gages near populated locations prone to rapidly moving landslides. Such improvements would probably require significant federal funding (cost from 0.5 to 1 million dollars). This alternative would also provide significant flood protection benefits. In large part, funding and logistical support required to implement this alternative would need to be provided by the Federal government.

Strategy III. Providing physical mitigation between high hazard sites, homes, or roads.

Strategy III. Mitigation measures (usually between the landslide initiation site and a home or road) should be considered when they:

- Can clearly reduce the risk to people.
- Provide a beneficial and desirable solution for the homeowner or road manager and the forest landowner.
- Provide an increased margin of safety.

Physical mitigation can reduce the likelihood of dangerous impacts from rapidly moving landslides. Mitigation can also lower other associated hazards (for example, trees blowing over onto homes). However, most mitigation strategies are relatively untested, especially mitigation for debris torrents that contain large wood. Multiple alternatives may be selected for Strategy III.

MITIGATION ALTERNATIVES

III.1) Mitigation will generally use structural (in the debris flow path) measures. Structural mitigation should be designed by a licensed professional. Mitigation guidelines should be developed in collaboration with geotechnical professionals.

III.2) A provision to allow landowners to remove trees on locations where the public safety risk from trees blowing over on landslide prone sites is higher than from rapidly moving landslides is important since there are cases where tree blow-down is the higher hazard on these sites. The department currently allows homeowners to remove trees from high risk sites if there is an apparent blow-down hazard and the trees could reach the home.

III.4) Homeowners who own landslide-prone forestland above their homes may be able to effectively manage this risk. If such operations are approved, information on the hazards and risk should be placed in the title so potential buyers are not unknowingly placed at high risk.

Strategy IV. Reducing the number of dwellings, and during extreme rainfall periods, vehicles in locations prone to rapidly moving landslide impact, since regardless of management there is high hazard in these locations. This strategy is designed to reduce the conflicts between forest management and persons in vulnerable locations.

Strategy IV. Note that removing structures from vulnerable locations can be the most effective option because:

- It will effectively reduce the number of people in dangerous locations.
- The economic value of the home is often lower than the value of the forest resource.
- People usually spend a great deal of time in homes (high exposure to the hazard).
- Even with an effective warning system, some people will not hear the warning, some will choose not to evacuate, and others may be impacted by debris flows during their evacuation.
- Senate Bill 12 prevents forest practices landslide and public safety provisions from being applied to new homes.

Conservation easements (acquired by the homeowner from the timber owner) can be used to eliminate the increased hazard associated with timber harvesting. However, these have no effect on the background (geologic hazard). Multiple alternatives may be selected for Strategy IV.

NON-FOREST PRACTICES RISK REDUCTION ALTERNATIVES (ALL NON-REGULATORY)

IV.1) The Board of Forestry could develop a formal policy to encourage voluntary agreements between forest landowners and homeowners. This policy could facilitate the purchase of existing homes in dangerous locations.

IV.2) Local governments can currently acquire development rights for properties hit and damaged or destroyed by rapidly moving landslides. Federal Emergency Management Agency (FEMA) funding is a logical source for acquiring these development rights. However, if these properties are acquired, local governments do not want to keep these lands because of liability concerns. The Board of Forestry could take over management of these lands as a more certain means to prevent future development.

IV.3) The Department of Transportation could implement special road management procedures for highways prone to rapidly moving landslides. These procedures would better inform motorists of rapidly moving landslides. They should also be designed to greatly reduce the likelihood of vehicles being stopped in locations prone to rapidly moving landslide impacts on the most critical highways.

IV.4) A joint Board of Forestry and Land Conservation and Development Commission Policy could be developed. This policy would state that development on debris flow- and torrent-prone sites is not compatible with forestry and ecological uses (Oregon Land-Use Goals 5 and 7). This policy should also encourage landowners to evaluate the value of timber versus the value of dwellings and to consider purchasing the land and property with the lower overall value.

IV.5) Develop guidance for geoscience investigations of proposed dwelling locations. This would include information on: using existing maps and other screening tools; field data collection; quantification of risk; typical allowable risk; and mitigation options. The department would lead this effort, with input from DOGAMI, certified engineering geologists, and registered professional engineers specializing in geotechnical engineering.

IV.6) Develop review guidance for local governments describing the standard elements of geoscience reports. ODF would provide information on how to determine maximum acceptable risk for their community. This guidance would also include information on coordination with state and federal experts. The department would lead this effort, with input from DOGAMI, certified engineering geologists, and registered professional engineers specializing in geotechnical engineering.

IV.7) Develop procedures for ODF review of home sites in further review areas. As currently planned, ODF would review plans for completeness, but would not evaluate the technical accuracy of plans. Review would apply to homes located in further review areas and where commercial forestlands exist within the debris flow shed.

IV.8) Conservation easements or outright land purchasing by the homeowner from the timber owner could be used to eliminate the increased hazard associated with timber harvesting. This would be another voluntary action between willing property owners. This alternative also requires a means to ensure the agreement is recorded on the property deed so that the property is not logged in the future. Note that this alternative provides a lower level of protection than does home purchasing.

IV.9) The provisions of Senate Bill 12 that do not allow local governments to prohibit new home construction in dangerous locations prone to rapidly moving landslides. This would allow true shared responsibility of the landslide and public safety risk, since, at the present time, only forest landowners are prohibited from managing some of these properties. This alternative would require support from both local governments and the Board of Forestry.

IV.10) An insurance or other fund could be used to facilitate acquisition of damaged properties and provide compensation for homeowners. At the present time, it is very difficult or impossible for homeowners to insure their homes from landslide damage. The lack of landslide mapping has made insurance (including through the Federal Flood Insurance program) impossible. However, with the completion of further review area maps Oregon may now meet the FEMA requirement for mapping "mudflow" hazards. Implementation of this recommendation would probably require a request through appropriate channels (Governor's office with congressional delegation support) to begin a trial program in Oregon.

Assessment of Alternatives

Benefits and costs of each alternative were assessed (Table 3). This assessment includes:

1. What issues (from Page 1) does the alternative deal with
2. How well the methods are developed (concept only, model or research, implemented)
3. How clear is the science on the effectiveness of this method (Strong, Limited, Professional judgement)
4. The benefits in terms of risk reduction to people (high, moderate, low, unknown)
5. The costs to landowners (high, moderate, low, unknown)
6. The cost to agencies (high, moderate, low, unknown)
7. The feasibility of field implementation of these alternatives (simple, complex, improbable)
8. The analysis required for implementation (none, economic, land area, feasibility, other)

Table 3. Preliminary Assessment of Alternatives

Table 3 provides a preliminary assessment of all the alternatives as they are now drafted. Note that recommendations may include less detail than current alternatives in some cases, especially where there is insufficient information to select a specific strategy. The assessment table describes the issues covered by each alternative, the science basis of the alternatives, costs, benefits, feasibility, and future analysis probably required before these alternatives could be implemented. The rows in Table 3 are the different alternatives, organized by strategy. The assessments found under each column heading as categorized below:

TABLE 3		**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
	Column Description of Column	The issues the alternative deals with	How well the methods are developed	How clear is the science on the effectiveness of this method	The benefits in in terms of risk reduction to people	The costs to the landowners	The cost to agencies	The feasibility of field implementation of these alternatives	The analysis required for implementation	Other pertinent information
	Choices for Column	*see list below table	<<concept only>> <<model or research>> <<implemented>>	<<strong>> <<limited>> <<professional judgement>>	<<high>> <<moderate>> <<low>> <<unknown>>	<<high>> <<moderate>> <<low>> <<unknown>>	<<high>> <<moderate>> <<low>> <<unknown>>	<<simple>> <<complex>>	<<economic>> <<land area>> <<feasibility>> <<none>>	
	Alternatives					***Assessments***				
		Issues	**Development**	**Science**	**Risk Reduction**	**Landowner Cost**	**Agency Costs**	**Feasibility**	**Analysis**	**Other Information**
I.	**Risk-based forest practices regulations**									
1.1	Exposure Categories	2, 4, 8	implemented	limited	unknown	unknown	low	simple	economic	A, B implemented
1.2	Matrix Table	4, 5, 9	model or research	limited	unknown	unknown	low	simple	economic	
I.A.	**Screening tools**									
A.1-3	Further review areas	2, 8	model or research	strong	unknown	low	unknown	simple	land area, feasibility	DOGAMI devel.
A.2-1	Homes and highways	8	concept only	strong	unknown	unknown	unknown	complex	feasibility	
A.2-2	Experience	8	implemented	prof. judg.	unknown	low	low	simple	none	Current practice
A.2-3	Operator	8	concept	prof. judg.	moderate	moderate	low	simple	economic	
I.B.	**Verification of landslide-prone locations**									
B.1	ODF-FPAC	5, 8	implemented	strong	moderate	moderate	low	simple	land area, economic	Similar cur. pract.
I.C	**Relative risk to people**									
C.1	Debris flow impacts study	1, 2, 4	concept only	limited	moderate	low	moderate	simple	economic, feasibility, land area	Finish in June
C.2	Model/fieldwork	1, 2, 4	model or research	limited	moderate	low	moderate	complex	economic, feasibility	
C.3	Geoscience professional	1, 2, 4	implemented	prof. judg.	moderate	moderate	low	simple	economic, feasibility	
I.D	**Practices to reduce or eliminate increased landslide occurrence**									
D.1	Not harvesting	1, 8, 9	implemented	strong	high	high	moderate	simple	economic	
D.2	No road construction	1, 8, 9	implemented	strong	high	high	moderate	simple	economic	
D.3	Silvicultural practices	1, 3, 9	concept only	strong	moderate	moderate	moderate	simple	economic, land area	
D.4	Root, canopy recovery	1, 3, 9	concept only	limited	unknown	moderate	moderate	complex	feasibility	
D.5	Less root, canopy loss	1, 3, 9	concept only	limited	unknown	moderate	moderate	complex	feasibility	
D.6	Geotech design roads	1, 3, 9	model or research	limited	moderate	moderate	low	complex	economic	
D.7	Large landslides	1, 3	implemented	strong	high	moderate	moderate	simple	economic	

I.E.	**Path management practices**									
E.1	Minimize slash	1, 3, 5	implemented	limited	moderate	low	low	simple	economic	Current practice
E.2	Remove slash	1, 3, 5	implemented	limited	moderate	low	low	simple	economic	
E.3	Large trees near people	1, 8, 9	concept only	limited	moderate	moderate	moderate	complex	economic, land area	
II.	**Getting people out of dangerous locations during storm**									
2.1	Homeowners information	2, 6	concept only	limited	moderate	low	moderate	simple	feasibility	
2.2	Notify existing residents	6, 7	concept only	prof. judg.	high	low	moderate	complex	feasibility	
2.3	Improve warning system	6, 7	concept only	prof. judg.	high	low	high	complex	feasibility	
III.	**Mitigation between sites and roads**									
3.1	Geotech des. structural	7, 8	model or research	limited	moderate	high	low	complex	economic, feasibility	
3.3	Removing wind hazard	7, 8	implemented	strong	high	low	low	simple	none	Current practice
3.4	Homeowner mngt. plan	7, 8	concept only	professional judgement	moderate	low	low	simple	feasibility	
IV.	**Keeping people out of dangerous locations**									
4.1	Voluntary mngt. policy	5	model or research	--	high	moderate	low	simple	feasibility	
4.2	Local gov. land to Board	6	concept only	--	high	low	moderate	complex	feasibility	
4.3	Road management	6	model or research	--	moderate	low	high	simple	feasibility	
4.4	Board-LCDC policy	6	concept only	--	moderate	low	low	complex	feasibility	
4.5	Geoscience guidance	7	model or research	limited	moderate	low	low	complex	feasibility	
4.6	Local guidance	2, 7	model or research	--	moderate	low	low	simple	none	
4.7	ODF review procedures	2, 7	model or research	--	moderate	low	low	simple	none	
4.8	Conservation easements	9	concept only	--	low	high	low	simple	feasibility	
4.9	Modify Senate Bill 12	7, 8	implemented	strong	high	moderate	moderate	simple	feasibility	
4.10	Insurance / FEMA	7, 8	concept only	limited	moderate	moderate	high	complex	economic	

List of Issues

1. How can forest practices regulations reduce the risk of serious bodily injury from rapidly moving landslides that originate on forestlands?
2. How can the Board develop rules to meet the statutory requirements of Senate Bill 12?
3. How can the Board develop rules to meet the statutory requirements of ORS 527-514 [Findings and analysis required prior to rule adoption]?
4. How should "substantial" risk of serious bodily injury be defined?
5. What can the Board do to make public safety regulations and other actions consistent with the Forestry Program for Oregon and existing Forest Practice rules for natural resource protection?
6. What can the Board do to ensure its actions compliment other State and local programs dealing with landslide risks?
7. What can be done to help all affected parties appropriately share responsibility to reduce risks associated with rapidly moving landslides?
8. What locations should be subject to special regulations for public safety?
9. How should the Board make decisions with limited scientific information, or where scientific uncertainty is significant?

XIII. RECOMMENDATIONS

The Project Team modified and combined alternatives as it deemed technically appropriate and in order to develop team consensus. Unless otherwise stated, the team agreed to all recommendations by consensus.

Strategy I. The Project Team recommends that the Board consider three exposure categories to assess risk and to determine the appropriate forest practices. These three categories, based on the likelihood of people being present during dangerous periods, are:
Exposure Category a. Habitable residences, schools, commercial or public offices. (Structures that are frequently - 25% or more of the time - occupied during the storm season - November 1 through April 30).
Exposure Category b. Roads with over 500 vehicles per day.
Exposure Category c. Barns, outbuildings, recreational dwellings, low-use public roads (Structures and roads where people are not usually present).

The Project Team also determined that setting the level of appropriate risk is a policy decision for the Board of Forestry, and not a technical decision for the Project Team. Based on the Exposure Category and hazard level, the appropriate forest practices can include no roads and harvesting for the highest risk, special silvicultural practices for intermediate risk, and natural resource protection practices for low public safety risk. Information on relative risk from rapidly moving landslides (pages 40 through 47 in the issue paper) should be considered in determining the level of appropriate risk for these different forest practices levels. During their discussions, the Board should consider residences differently from highways, since it is possible to control traffic on highways (and thus keep people away from the hazard). Also, there may be instances where hazard is so extreme that it is appropriate to raise the protection level.

Sub-strategy 1.A. The Project Team recommends that Further Review Area Maps be used to identify locations prone to rapidly moving landslides (alternative I.A.1-3). The Department of Geology and Mineral Industries is currently developing these maps as directed by Senate Bill 12, and plans to have them complete in the spring of 2002. The Project Team also recommends that these maps be updated as new information becomes available.

The Project Team recommends that operators should be required to identify structures and roads within mapped further review areas below any operation that also contains further review areas within the operation area (I.A.2-3). The department should notify operators that their operation contains further review area(s), and the department should also share responsibility to find homes and, where appropriate, roads by independently checking these locations (alternative I.A.2-2). Finally, as a longer-term project, the Project Team recommends that the department investigate developing a map or other inventory tool (alternative I.A.2-1) that accurately identifies the locations of homes and highways and busy roads (such a map currently does not exist).

Sub-strategy 1.B. The Project Team recommends that the Board adopt into rule form the current high risk site criteria used by the department (alternative I.B.1). This was also a consensus recommendation of the Forest Practices Advisory Committee (FPAC). These locations would be identified as "high hazard locations" not "high risk sites," since risk depends on conditions along the debris flow/torrent path. Oregon Department of Forestry (ODF) will screen and notify landowners about high hazard locations.

Sub-strategy 1.C. The Project Team recommends that the department evaluate rapidly moving landslide hazard using information from the debris flow impacts study (alternative 1.C.1), as described in Appendix 4. Hazard would be based on the physical conditions in the debris flow shed, and on the specific location of the vulnerable population. As more information becomes available, these criteria should be modified as appropriate. The department should use debris flow runout models (alternative I.C.2) to help validate these hazard evaluation methods. Finally, if a landowner so chooses, a geoscience professional should be used to collect specific physical information in the field to better assess hazard (alternative I.C.3). The department should let landowners know when the use of a geoscientist is prudent, and should review all geoscientist-provided information to ensure it is based on field-specific physical information.

Sub-strategy 1.D. The Project Team recommends that the Board adopt rules that do not allow any reduction in root strength or canopy cover in the **highest risk situations** (alternative 1.D.1). This would allow no harvesting, except to remove dead trees, to prevent loss of other vegetation by disease, or to remove trees from sites that have already failed and, in these cases, only where the operator can demonstrate that the operation results in no increased landslide hazard. Department geotechnical specialists would make the final determination whether the operation increases landslide risk. The Project T eam also recommends that the Board adopt rules that do not allow road construction in the highest hazard locations (alternative I.D.2). In limited cases, road reconstruction should be allowed if the operator can show that this results in a reduced landslide hazard.

The Project Team recommends that the Board adopt rules that describe silvicultural practices to limit the increase in landslide hazard associated with vegetation removal for **intermediate risk situations** (alternative 1.D.3). These silvicultural practices include limits on the acreage in vulnerable condition by landowner or operation. The team also recommends that practices to ensure more rapid canopy and root recovery be developed into rule form (alternative 1.D.4) and similar practices to ensure less loss of canopy and roots (for thinning) also be developed (alternative 1.D.5).

The Project Team recommends that roads constructed on high hazard locations and with **intermediate downslope public safety risk** follow site specific recommendations of a geotechnical specialist to ensure drainage is not diverted to any high hazard location (alternative 1.D.6). The Project Team also recommends that forest road construction operations that might result in large, rapidly moving landslides be subject to special public safety review (alternative

1.D.6). Fills in narrow canyons and waste disposal areas are currently only reviewed for natural resource protection purposes.

Sub-strategy 1.E. The Project Team recommends that the Board adopt rules that require operators to fall and yard trees to minimize slash and other debris accumulations in channels above homes and roads (alternative 1.E.1). Operators should be required to remove accumulations of slash that enter these channels (alternative 1.E.2). The Project Team also recommends leaving larger trees standing next to the lower (6 to something under 20 percent) gradient part of debris torrent-prone channels (alternative 1.E.3), since there is limited evidence that trees in these locations may reduce debris torrent travel distance. The Project Team also recommends that the Board discuss the policy implications of the differences between debris management for fish as compared to public safety (since wood is beneficial for fish habitat, but is likely to increase public safety dangers associated with rapidly moving landslides).

Strategy II. The Project Team recommends that the department work with other appropriate agencies and technical experts to develop information for persons living in locations prone to rapidly moving landslides (alternative II.1). The team also recommends that the department work with local governments to provide this information to these residents (alternative II.2). The team also strongly recommends that the Governor's Interagency Hazard Mitigation Team, with the assistance of Oregon State University, lead an effort to obtain additional radar site and real-time rain gages so that the current warning debris flow warning system is significantly improved (alternative II.3). This alternative will also improve flood forecasting and warnings in the Coast Range.

Strategy III. The Project Team recommends that mitigation (actions to control or re-direct rapidly moving landslides) should generally use structural measures that are designed by a licensed professional (alternative III.1). This will be the responsibility of forest landowners with input from affected homeowners and not the responsibility of State or local government. The Project Team also recommends that rules be drafted to specifically allow landowners to remove trees on locations where the public safety risk from trees blowing over on specific sites is higher than from rapidly moving landslides initiating on those same sites (alternative III.2).

The Project Team believes that homeowners' management of landslide-prone forestland above their homes (alternative III.4) is a policy consideration for the Board. Specifically, are there situations where, despite the landslide hazard, a homeowner may conduct forest practices on landslide-prone terrain above their own home? The Board should consider potential impacts for persons who were not party to these decisions (renters, children, and potential home-buyers).

Strategy IV. The Project Team recommends that the Board of Forestry develop a formal policy to encourage voluntary agreements between forest landowners and homeowners to remove or relocate structures in locations prone to rapidly moving landslides (alternative IV.1). This policy should then be effectively communicated to the affected parties. The Office of Emergency Management should effectively encourage local governments to acquire properties hit and damaged or destroyed by rapidly moving landslides (alternative IV.2). Since local governments may not want to keep these properties because of liability concerns, Board management, instead of local government management, of these properties could encourage more local governments to make these acquisitions. The Project Team also recommends that the Board develop a joint policy with the Land Conservation and Development Commission stating that development of new homes in locations prone to rapidly moving landslides is not compatible with forestry uses (alternative IV.4).

The Project Team recommends that the Department of Transportation work with the Department of Forestry, Department of Geology and Mineral Industries, and the Office of Emergency Management to develop road management procedures for highways prone to rapidly moving landslides (alternative IV.3). These procedures should better inform motorists of rapidly moving landslides and greatly reduce the likelihood of vehicles being stopped in locations prone to rapidly moving landslide impacts on the most critical highways. The department should report back to the Board on the results of this collaborative effort.

The Project Team recommends that the department develop three different guidance documents for:

- Geoscience investigations of proposed dwelling locations (alternative IV.5);
- Local governments' review of these investigations, describing the standard elements of geoscience reports (alternative IV.6); and
- Procedures for ODF review of home sites in further review areas (alternative IV.7).

The Project Team **strongly** recommends that the Board work with local governments and the legislature to change the provisions of Senate Bill 12 that currently do not allow local governments to prohibit new home construction in dangerous locations prone to rapidly moving landslides (alternative IV.9).

The Project Team recommends that the Office of Emergency Management and the Department of Land Conservation Development work together to investigate options for developing an insurance program based on the Further Review Area Maps currently being developed and on the authorization to include mudflow-prone areas in the flood insurance program.

Finally, a majority of Project Team members recommend that the Board develop possible strategies for landowner compensation, since in some cases, landowners may be precluded from harvesting a substantial portion of their property.

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Appendix 1: Full Text of Senate Bill 12

70th OREGON LEGISLATIVE ASSEMBLY--1999 Regular Session

Enrolled
Senate Bill 12

Printed pursuant to Senate Interim Rule 213.28 by order of the President of the Senate in conformance with presession filing rules, indicating neither advocacy nor opposition on the part of the President (at the request of Joint Interim Task Force on Landslides and Public Safety)

Relating to protection of public from landslide hazards; creating new provisions; amending ORS 215.130, 527.630, 527.710 and 527.714 and section 8, chapter 565, Oregon Laws 1997; and appropriating money.

Be It Enacted by the People of the State of Oregon:

SECTION 1. { + As used in sections 1 to 9 of this 1999 Act:

(1) 'Further review area' means an area of land within which further site specific review should occur before land management or building activities begin because either the State Department of Geology and Mineral Industries or the State Forestry Department determines that the area reasonably could be expected to include sites that experience rapidly moving landslides as a result of excessive rainfall.

(2) 'Landslide' means any detached mass of soil, rock or debris that is of sufficient size to cause damage and that moves down a slope or a stream channel.

(3) 'Rapidly moving landslide' means a landslide that is difficult for people to outrun or escape. + }

SECTION 2. { + The Legislative Assembly declares that it is the policy of the State of Oregon that:

(1) Each property owner, each highway user and all federal, state and local governments share the responsibility for making sound decisions regarding activities that may affect landslide hazards and the associated risks of property damage or personal injury.

(2) In keeping with the concept of shared responsibility where individuals are primarily responsible for making sound decisions to protect personal interests, regulation applied pursuant to sections 1 to 7 of this 1999 Act shall be restricted to reducing the risk of serious bodily injury or death that may result from rapidly moving landslides.

(3) In recognition of the need for consistent treatment and coordination of actions relating to rapidly moving landslides and because of the potential for serious bodily injury or death as a result of rapidly moving landslides and the effect of rapidly moving landslides on the ability of people to use their property,

sections 1 to 7 of this 1999 Act shall be regarded as the controlling policy of this state for rapidly moving landslides. + }

SECTION 3. { + The Legislative Assembly finds that:

(1) Many locations in Oregon are subject to naturally occurring landslide hazards, and some human activities may accelerate the incidence or increase the adverse effects of those hazards.

(2) Rapidly moving landslides present the greatest risk to human life, and persons living in or traveling through areas prone to rapidly moving landslides are at increased risk of serious bodily injury or death.

(3) Although some risk from rapidly moving landslides can be mitigated through proper siting and construction techniques, sites that are vulnerable to impact from rapidly moving landslides are generally unsuitable for permanent habitation.

(4) Activities that require sound decisions to mitigate rapidly moving landslide hazards and risks include but are not limited to:

(a) Siting or constructing homes or other structures in areas prone to rapidly moving landslides;

(b) Occupying existing homes or other structures in areas prone to rapidly moving landslides during periods of high risk due to heavy or extended rainfall;

(c) Conducting land management activities that may adversely alter the susceptibility of land to rapidly moving landslides; and

(d) Operating motor vehicles in areas known to be subject to rapidly moving landslides. + }

SECTION 4. { + (1) In order to reduce the risk of serious bodily injury or death resulting from rapidly moving landslides, a local government:

(a) Shall exercise all available authority to protect the public during emergencies, consistent with ORS 401.015.

(b) May require a geotechnical report and, if a report is required, shall provide for a coordinated review of the geotechnical report by the State Department of Geology and Mineral Industries or the State Forestry Department, as appropriate, before issuing a building permit for a site in a further review area.

(c) Except those structures exempt from building codes under ORS 455.310 and 455.315, shall regulate through mitigation measures and site development standards the siting of dwellings and other structures designed for human occupancy, including those being restored under ORS 215.130 (6), in further review areas where there is evidence of substantial risk for rapidly moving landslides. All final decisions under this paragraph and paragraph (b) of this subsection are the responsibility of the local government with jurisdiction over the site. A local government may not delegate such final decisions to any state agency.

(d) Shall maintain a record, available to the public, of properties for which a geotechnical report has been prepared within the jurisdiction of the local government.

(2) A landowner allowed a building permit under subsection (1)(c) of this section shall sign a statement that shall:

(a) Be recorded with the county clerk of the county in which the property is located, in which the landowner acknowledges that the landowner may not in the future bring any action against an adjacent landowner about the effects of rapidly moving landslides on or adjacent to the landowner's property; and

(b) Record in the deed records for the county where the lot or parcel is located a nonrevocable deed restriction that the landowner signs and acknowledges, that contains a legal description complying with ORS 93.600 and that prohibits any present or future owner of the property from bringing any action against an adjacent landowner about the effects of rapidly moving landslides on or adjacent to the property.

(3) Forest practice rules adopted under ORS 527.710 (11) shall not apply to risk situations arising solely from the construction of a building permitted under subsection (1)(c) of this section after the effective date of this 1999 Act.

(4) The following state agencies shall implement the following specific responsibilities to reduce the risk of serious bodily injury or death resulting from rapidly moving landslides:

(a) The State Department of Geology and Mineral Industries shall:

(A) Identify and map further review areas selected in cooperation with local governments and in coordination with the State Forestry Department, and provide technical assistance to local governments to facilitate the use and application of this information pursuant to subsection (1)(b) of this section; and

(B) Provide public education regarding landslide hazards.

(b) The State Forestry Department shall regulate forest operations to reduce the risk of serious bodily injury or death from rapidly moving landslides directly related to forest operations, and assist local governments in the siting review of permanent dwellings on and adjacent to forestlands in further review areas pursuant to subsection (1)(b) of this section.

(c) The Land Conservation and Development Commission may take steps under its existing authority to assist local governments to appropriately apply the requirements of subsection (1)(c) of this section.

(d) The Department of Transportation shall provide warnings to motorists during periods determined to be of highest risk of rapidly moving landslides along areas on state highways with a history of being most vulnerable to rapidly moving landslides.

(e) The Office of Emergency Management of the Department of State Police shall coordinate state resources for rapid and effective response to landslide-related emergencies.

(5) Notwithstanding any other provision of law, any state or local agency adopting rules related to the risk of serious bodily injury or death from rapidly moving landslides shall do so only in conformance with the policies and provisions of sections 1 to 7 of this 1999 Act.

(6) No state or local agency may adopt or enact any rule or ordinance for the purpose of reducing risk of serious bodily injury or death from rapidly moving landslides that limits the use of land that is in addition to land identified as a further review area by the State Department of Geology and Mineral Industries or the State Forestry Department pursuant to subsection (4) of this section.

(7) Except as provided in ORS 527.710 or in Oregon's ocean and coastal land use planning goals, no state agency may adopt criteria regulating activities for the purpose of reducing risk of serious bodily injury or death from rapidly moving landslides on lands subject to the provisions of sections 1 to 7 of this 1999 Act that are more restrictive than the criteria adopted by a local government pursuant to subsection (1)(c) of this section.

SECTION 5. { + (1) Regulations adopted by a local government to regulate the siting of dwellings and other structures designed for human occupancy through mitigation measures and site development standards as required under section 4 (1)(c) of this 1999 Act shall include the following decision process:

(a) A determination that the dwelling or other structure is allowed under applicable land use regulations and whether the proposed site for the dwelling or other structure is located within a portion of the further review area that poses a risk of serious bodily injury or death resulting from a rapidly moving landslide.

(b) If an alternative site on the same lot or parcel that does not require mitigation is available:

(A) The local government first shall require the property owner to site the dwelling or other structure at the alternative site, so long as the cost of relocating does not exceed $20,000.

(B) If the cost of relocating exceeds $20,000, and the local government has adopted a transfer of development rights program that complies with sections 6 and 7 of this 1999 Act, the local government shall allow the property owner either to:

(i) Participate in the local government's transfer of development rights program; or

(ii) Construct the dwelling or other structure on the alternative site even though the cost of relocating exceeds $20,000.

(C) If the cost of relocating exceeds $20,000, and the local government has not adopted a transfer of development rights program, the local government shall allow the property owner either to:

(i) Construct the dwelling or other structure at the alternative site; or

(ii) Pursue mitigation available under paragraph (c) of this subsection.

(c) If an alternative site on the same lot or parcel that does not require mitigation is not available and if development of the site complies with all other applicable requirements:

(A) If the cost of adequate mitigation is less than $10,000, the local government shall allow construction of the dwelling or other structure if the property owner completes the mitigation measures.

(B) If the cost of adequate mitigation exceeds $10,000, and the local government has adopted a transfer of development rights program, the local government shall allow the property owner to:

(i) Participate in the local government's transfer of development rights program; or

(ii) Construct the dwelling or other structure on the proposed site and complete adequate mitigation even though the cost of mitigation exceeds $10,000.

(C) If the cost of adequate mitigation exceeds $10,000, and the local government has not adopted a transfer of development rights program, the local government shall allow the property owner to take either of the following actions:

(i) Site the dwelling or other structure at an alternative site in the further review area and implement mitigation measures. The local government may not require the property owner to incur a combined relocation and mitigation cost of more than $20,000 if the property owner proceeds with this option.

(ii) Site the dwelling or other structure at the original proposed site and implement mitigation measures. The local government may not require the property owner to incur more than $10,000 in costs for implementing mitigation measures if the property owner proceeds with this option.

(2) Nothing in this section prohibits a property owner from constructing a dwelling or other structure on the lot or parcel and agreeing to pay mitigation costs that exceed the amount established under subsection (1) of this section. + }

SECTION 6. { + (1) For a further review area, a local government may not impose mitigation requirements under section 4 (1)(c) of this 1999 Act that require a property owner to implement mitigation measures for which the cost exceeds $10,000 or require the property owner to expend more than $20,000 in site development costs resulting from changing the site of a dwelling or other structure unless the local government has adopted a transfer of development rights program.

(2) A transfer of development rights program established pursuant to this section shall:

(a) Allow a development right to be transferred from a lot or parcel that is located within a further review area to another area within the city or county and that is not otherwise eligible for an additional dwelling under existing comprehensive plan and zoning designations.

(b) Provide that the transfer opportunity is available to a property owner only after:

(A) An application for a dwelling or other structure on a lot or parcel located within a further review area establishes that the dwelling or structure would be authorized under applicable local ordinances in effect on January 1, 1999, and under statutes and administrative rules;

(B) The local government determines that there are no alternative building sites on the same lot or parcel where mitigation would not be required or where site development costs resulting from changing the site exceed the limit established under section 5 (1)(b) of this 1999 Act; and

(C) The local government determines that the cost of mitigation requirements will exceed $10,000 or the site development costs resulting from changing the site will exceed $20,000.

(3) In adopting a transfer of development rights program, the local government shall identify one or more areas on plan and zoning maps as receiving areas for transferred development rights. Receiving areas shall authorize new dwelling opportunities that are not otherwise eligible for an additional dwelling under existing comprehensive plan and zoning designations transferred in accordance with this section. New dwelling opportunities shall include but need not be limited to a second dwelling opportunity on the same lot or parcel and the creation of additional parcels or lots, provided such new dwelling opportunities and land divisions are allowed under ORS chapters 197, 215 and 227, and goals and rules adopted thereunder, but were not allowed by state law or local land use regulations prior to the effective date of this 1999 Act.

(4) The local government shall adopt findings demonstrating that the number of dwelling opportunities provided exceeds the projected number of transferred rights based on the further review areas that are inside the boundaries of the local government.

(5) A local government shall monitor the transfer of development rights program and make adjustments as necessary to ensure an adequate supply of financially equitable transfer opportunities in designated receiving areas.

(6) A person who transfers or conveys the development rights to a lot or parcel under a transfer of development rights program established pursuant to this section shall record in the deed records for the county where the lot or parcel is located a nonrevocable deed restriction prohibiting future development of the lot or parcel.

(7) The governing body of a city or county may establish a system to facilitate the transfer of development rights by purchasing any number of such rights and subsequently offering them for sale.

(8) A city or county with a transfer of development rights program established pursuant to this section shall maintain a registry of all lots or parcels from which rights have been transferred, the lots or parcels to which rights have been transferred and the allowable development level for each lot or parcel following transfer. + }

SECTION 7. { + In establishing a transfer of development rights program under section 6 of this 1999 Act, a local government may enter into an intergovernmental agreement with another local government to allow for transferred development rights that are outside the boundaries of the local government. + }

SECTION 8. { + The Department of Land Conservation and Development shall award a grant to a local government for the purpose of developing a model program for the mitigation of hazards and transfer of development rights that may be adopted by other local governments in order to satisfy the requirements of sections 5 to 7 of this 1999 Act. The pilot program shall include the development of model ordinances, regulations and procedures for mitigation of hazards and for allowing the transfer of development rights under sections 5 to 7 of this 1999 Act. + }

SECTION 9. { + (1) The Legislative Assembly finds that it is in the public interest to limit the siting in further review areas of dwellings and other structures designed for human occupancy. In order to further this public interest, it is necessary to postpone the siting of dwellings and other structures in further review areas until local governments have an opportunity to enact regulations as required under section 4 (1)(c) of this 1999 Act and if the local government chooses, a transfer of development rights program pursuant to sections 5 to 7 of this 1999 Act.

(2) The Legislative Assembly declares that, notwithstanding the provisions of section 5 of this 1999 Act, for the 10-month period following the date the State Department of Geology and Mineral Industries notifies the local government that all identification and mapping of further review areas under section 4 (4)(a) of this 1999 Act are prepared for the local government, that local government shall not allow the siting of a dwelling or other structure in a further review area without adequate mitigation unless the local government has adopted the regulations required under section 4 (1)(c) of this 1999 Act and a transfer of development rights program that satisfies the requirements of sections 5 to 7 of this 1999 Act.

(3) Within 10 months after a local government receives notification under subsection (2) of this section, the local government shall adopt the regulations required under section 5 to 7 of this 1999 Act. + }

SECTION 10. ORS 215.130 is amended to read:

215.130. (1) Any legislative ordinance relating to land use planning or zoning shall be a local law within the meaning of, and subject to, ORS 250.155 to 250.235.

(2) An ordinance designed to carry out a county comprehensive plan and a county comprehensive plan shall apply to:

(a) The area within the county also within the boundaries of a city as a result of extending the boundaries of the city or creating a new city unless, or until the city has by ordinance or other provision provided otherwise; and

(b) The area within the county also within the boundaries of a city if the governing body of such city adopts an ordinance declaring the area within its boundaries subject to the county's land use planning and regulatory ordinances, officers and procedures and the county governing body consents to the conferral of jurisdiction.

(3) An area within the jurisdiction of city land use planning and regulatory provisions that is withdrawn from the city or an area within a city that disincorporates shall remain subject to such plans and regulations which shall be administered by the county until the county provides otherwise.

(4) County ordinances designed to implement a county comprehensive plan shall apply to publicly owned property.

(5) The lawful use of any building, structure or land at the time of the enactment or amendment of any zoning ordinance or regulation may be continued. Alteration of any such use may be permitted subject to subsection (9) of this section. Alteration of any such use shall be permitted when necessary to comply with any lawful requirement for alteration in the use. Except as provided in ORS 215.215, a county shall not place conditions upon the continuation or alteration of a use described under this subsection when necessary to comply with state or local health or safety requirements, or to maintain in good repair the existing structures associated with the use. A change of ownership or occupancy shall be permitted.

(6) Restoration or replacement of any use described in subsection (5) of this section may be permitted when the restoration is made necessary by fire, other casualty or natural disaster. Restoration or replacement shall be commenced within one year from the occurrence of the fire, casualty or natural disaster. { + If restoration or replacement is necessary under this subsection, restoration or replacement shall be done in compliance with section 4 (1)(c) of this 1999 Act. + }

(7) Any use described in subsection (5) of this section may not be resumed after a period of interruption or abandonment unless the resumed use conforms with the requirements of zoning ordinances or regulations applicable at the time of the proposed resumption.

(8) Any proposal for the verification or alteration of a use under subsection (5) of this section, except an alteration necessary to comply with a lawful requirement, for the restoration or replacement of a use under subsection (6) of this section or for the resumption of a use under subsection (7) of this section shall be subject to the provisions of ORS 215.416. An initial decision by the county or its designate on a proposal for the alteration of a use described in subsection (5) of this section shall be made as an administrative decision without public hearing in the manner provided in ORS 215.416 (11).

(9) As used in this section, 'alteration' of a nonconforming use includes:

(a) A change in the use of no greater adverse impact to the neighborhood; and

(b) A change in the structure or physical improvements of no greater adverse impact to the neighborhood.

(10) A local government may adopt standards and procedures to implement the provisions of this section. The standards and procedures may include but are not limited to the following:
(a) For purposes of verification of a use under subsection (5) of this section, a county may adopt procedures that allow an applicant for verification to prove the existence, continuity, nature and extent of the use only for the 10-year period immediately preceding the date of application. Evidence proving the existence, continuity, nature and extent of the use for the 10-year period preceding application creates a rebuttable presumption that the use, as proven, lawfully existed at the time the applicable zoning ordinance or regulation was adopted and has continued uninterrupted until the date of application;
(b) Establishing criteria to determine when a use has been interrupted or abandoned under subsection (7) of this section; or
(c) Conditioning approval of the alteration of a use in a manner calculated to ensure mitigation of adverse impacts as described in subsection (9) of this section.

SECTION 11. ORS 527.630 is amended to read:
527.630. (1) Forests make a vital contribution to Oregon by providing jobs, products, tax base and other social and economic benefits, by helping to maintain forest tree species, soil, air and water resources and by providing a habitat for wildlife and aquatic life. Therefore, it is declared to be the public policy of the State of Oregon to encourage economically efficient forest practices that { - assure - } { + ensure + } the continuous growing and harvesting of forest tree species and the maintenance of forestland for such purposes as the leading use on privately owned land, consistent with sound management of soil, air, water, fish and wildlife resources and scenic resources within visually sensitive corridors as provided in ORS 527.755 { - that assures - } { + and to ensure + } the continuous benefits of those resources for future generations of Oregonians.
(2) It is recognized that operations on forestland are already subject to other laws and to regulations of other agencies which deal primarily with consequences of such operations rather than the manner in which operations are conducted. It is further recognized that it is essential to avoid uncertainty and confusion in enforcement and implementation of such laws and regulations and in planning and carrying out operations on forestlands.
(3) To encourage forest practices implementing the policy of ORS 527.610 to 527.770 and 527.990 and 527.992, it is declared to be in the public interest to vest in the State Board of Forestry exclusive authority to develop and enforce statewide and regional rules pursuant to ORS 527.710 and to coordinate with other state agencies and local governments which are concerned with the forest environment.
(4) The board may adopt and enforce rules addressing scenic considerations only in accordance with ORS 527.755.
{ + (5) The board shall adopt and enforce forest practice rules to reduce the risk of serious bodily injury or death from a

rapidly moving landslide only in accordance with ORS 527.710 (11). As used in this subsection, 'rapidly moving landslide' has the meaning given in section 1 of this 1999 Act. + }

{ - (5) - } { + (6) + } The State of Oregon should provide a stable regulatory environment to encourage investment in private forestlands.

SECTION 12. ORS 527.710 is amended to read:

527.710. (1) In carrying out the purposes of ORS 527.610 to 527.770, 527.990 (1) and 527.992, the State Board of Forestry shall adopt, in accordance with applicable provisions of ORS 183.310 to 183.550, rules to be administered by the State Forester establishing standards for forest practices in each region or subregion.

(2) The rules shall { - assure - } { + ensure + } the continuous growing and harvesting of forest tree species. Consistent with ORS 527.630, the rules shall provide for the overall maintenance of the following resources:

(a) Air quality;

(b) Water resources, including but not limited to sources of domestic drinking water;

(c) Soil productivity; and

(d) Fish and wildlife.

(3)(a) In addition to its rulemaking responsibilities under subsection (2) of this section, the board shall collect and analyze the best available information and establish inventories of the following resource sites needing protection:

(A) Threatened and endangered fish and wildlife species identified on lists that are adopted, by rule, by the State Fish and Wildlife Commission or are federally listed under the Endangered Species Act of 1973 as amended;

(B) Sensitive bird nesting, roosting and watering sites;

(C) Biological sites that are ecologically and scientifically significant; and

(D) Significant wetlands.

(b) The board shall determine whether forest practices would conflict with resource sites in the inventories required by paragraph (a) of this subsection. If the board determines that one or more forest practices would conflict with resource sites in the inventory, the board shall consider the consequences of the conflicting uses and determine appropriate levels of protection.

(c) Based upon the analysis required by paragraph (b) of this subsection, and consistent with the policies of ORS 527.630, the board shall adopt rules appropriate to protect resource sites in the inventories required by paragraph (a) of this subsection.

(4) Before adopting rules under subsection (1) of this section, the board shall consult with other agencies of this state or any of its political subdivisions that have functions with respect to the purposes specified in ORS 527.630 or programs affected by forest operations. Agencies and programs subject to consultation under this subsection include, but are not limited to:

(a) Air and water pollution programs administered by the Department of Environmental Quality under ORS chapters 468A and 468B and ORS 477.013 and 477.515 to 477.532;

(b) Mining operation programs administered by the Department of Geology and Mineral Industries under ORS 516.010 to 516.130 and ORS chapter 517;

(c) Game fish and wildlife, commercial fishing, licensing, wildlife and bird refuge and fish habitat improvement tax incentive programs administered by the State Department of Fish and Wildlife under ORS 272.060, 315.134, 501.005 to 501.540 and ORS chapters 496, 498, 506 and 509;

(d) Park land, Willamette River Greenway, scenic waterway and recreation trail programs administered by the State Parks and Recreation Department under ORS 358.475 to 358.565, 390.310 to 390.368, 390.805 to 390.925, 390.950 to 390.989 and 390.121;

(e) The programs administered by the Columbia River Gorge Commission under Public Law 99-663 and ORS 196.110 and 196.150;

(f) Removal and fill, natural heritage conservation and natural heritage conservation tax incentive programs administered by the State Land Board and the Division of State Lands under ORS 196.800 to 196.900, 273.553 to 273.591, 307.550, 307.560 and 541.700 to 541.990;

(g) Federal Safe Drinking Water Act programs administered by the Health Division under ORS 448.273 to 448.990;

(h) Natural heritage conservation programs administered by the Natural Heritage Advisory Council under ORS 273.553 to 273.591, 307.550 and 307.560;

(i) Open space land tax incentive programs administered by cities and counties under ORS 308.740 to 308.790;

(j) Water resources programs administered by the Water Resources Department under ORS 536.220 to 536.540; and

(k) Pesticide control programs administered by the State Department of Agriculture under ORS chapter 634.

(5) In carrying out the provisions of subsection (4) of this section, the board shall consider and accommodate the rules and programs of other agencies to the extent deemed by the board to be appropriate and consistent with the purposes of ORS 527.630.

(6) The board shall adopt rules to meet the purposes of another agency's regulatory program where it is the intent of the board to administer the other agency's program on forestland and where the other agency concurs by rule. An operation performed in compliance with the board's rules shall be deemed to comply with the other agency's program.

(7)(a) The board may enter into cooperative agreements or contracts necessary in carrying out the purposes specified in ORS 527.630, including but not limited to stewardship agreements as described in ORS 527.662.

(b) The State Forestry Department shall enter into agreements with appropriate state agencies for joint monitoring of the effectiveness of forest practice rules in protecting forest resources and water quality.

(8) If based upon the analysis required in section 15 (2)(f), chapter 919, Oregon Laws 1991, and as the results become

available, the board determines that additional rules are necessary to protect forest resources pursuant to ORS 527.630, the board shall adopt forest practice rules that reduce to the degree practicable the adverse impacts of cumulative effects of forest practices on air and water quality, soil productivity, fish and wildlife resources and watersheds. Such rules shall include a process for determining areas where adverse impacts from cumulative effects have occurred or are likely to occur, and may require that a written plan be submitted for harvests in such areas.

(9)(a) The State Forester, in cooperation with the State Department of Fish and Wildlife, shall identify streams for which restoration of habitat would be environmentally beneficial. The State Forester shall select as a priority those streams where restoration efforts will provide the greatest benefits to fish and wildlife, and to streambank and streambed stability.

(b) For those streams identified in paragraph (a) of this subsection, the State Forester shall encourage landowners to enter into cooperative agreements with appropriate state agencies for conduct of restoration activities.

(c) The board, in consultation with appropriate state agencies, shall study and identify methods for restoring or enhancing fish and wildlife populations through restoration and rehabilitation of sites beneficial to fish and wildlife.

(d) The board shall adopt rules to implement the findings of this subsection.

(10) The board shall adopt rules that provide the State Forester with authority to condition the approval of plans required under ORS 527.670 (2) and (3) when the State Forester makes a determination that there is evidence of a potential threat to resources protected under this section by controlling method, timing and extent of harvest when the forester determines such limitations are necessary to achieve the objectives of ORS 527.630.

{ + (11) In addition to its responsibilities under subsections (1) to (3) of this section, the board shall adopt rules to reduce the risk of serious bodily injury or death caused by a rapidly moving landslide directly related to forest practices. The rules shall consider the exposure of the public to these safety risks and shall include appropriate practices designed to reduce the occurrence, timing or effects of rapidly moving landslides. As used in this subsection, 'rapidly moving landslide' has the meaning given that term in section 1 of this 1999 Act. + }

SECTION 13. ORS 527.714 is amended to read:

527.714. (1) The rulemaking authority of the State Board of Forestry under ORS 527.610 to 527.770 consists generally of the following three types of rules:

(a) Rules adopted to implement administration, procedures or enforcement of ORS 527.610 to 527.770 that support but do not directly regulate standards of forest practices.

(b) Rules adopted to provide definitions or procedures for forest practices where the standards are set in statute.
(c) Rules adopted to implement the provisions of ORS 527.710 (2), (3), (6), (8), (9) { + , + } { - and - } (10) { + and (11) + } that grant broad discretion to the board and that set standards for forest practices not specifically addressed in statute.
(2) When considering the adoption of a rule, and prior to the notice required pursuant to ORS 183.335, the board shall determine which type of rule described in subsection (1) of this section is being considered.
(3) If the board determines that a proposed rule is of the type described in subsection (1)(a) or (b) of this section, or if the proposed rule is designed only to clarify the meaning of rules already adopted or to make minor adjustments to rules already adopted that are of the type described in subsection (1)(c) of this section, rulemaking may proceed in accordance with ORS 183.325 to 183.410 and is not subject to the provisions of this section.
(4) If the board determines that a proposed rule is of the type described in subsection (1)(c) of this section, and the proposed rule would change the standards for forest practices, the board shall describe in its rule the purpose of the rule and the level of protection that is desired.
(5) If the board determines that a proposed rule is of the type described in subsection (1)(c) of this section, including a proposed amendment to an existing rule not qualifying under subsection (3) of this section, and the proposed rule would provide new or increased standards for forest practices, the board may adopt such a rule only after determining that the following facts exist and standards are met:
(a) If forest practices continue to be conducted under existing regulations, there is monitoring or research evidence that documents that degradation of resources maintained under ORS 527.710 (2) or (3) is likely { + , or in the case of rules proposed under ORS 527.710 (11), that there is a substantial risk of serious bodily injury or death + };
(b) If the resource to be protected is a wildlife species, the scientific or biological status of a species or resource site to be protected by the proposed rule has been documented using best available information;
(c) The proposed rule reflects available scientific information, the results of relevant monitoring and, as appropriate, adequate field evaluation at representative locations in Oregon;
(d) The objectives of the proposed rule are clearly defined, and the restrictions placed on forest practices as a result of adoption of the proposed rule:
(A) Are to prevent harm or provide benefits to the resource or resource site for which protection is sought { + , or in the case of rules proposed under ORS 527.710 (11), to reduce risk of serious bodily injury or death + }; and

(B) Are directly related to the objective of the proposed rule and substantially advance its purpose;
(e) The availability, effectiveness and feasibility of alternatives to the proposed rule, including nonregulatory alternatives, were considered, and the alternative chosen is the least burdensome to landowners and timber owners, in the aggregate, while still achieving the desired level of protection; and
(f) The benefits to the resource { + , or in the case of rules proposed under ORS 527.710 (11), the benefits in reduction of risk of serious bodily injury or death, + } that would be achieved by adopting the rule are in proportion to the degree that existing practices of the landowners and timber owners, in the aggregate, are contributing to the overall resource concern that the proposed rule is intended to address.
(6) Nothing in subsection (5) of this section:
(a) Requires the board to call witnesses;
(b) Requires the board to allow cross-examination of witnesses;
(c) Restricts ex parte communications with the board or requires the board to place statements of such communications on the record;
(d) Requires verbatim transcripts of records of proceedings; or
(e) Requires depositions, discovery or subpoenas.
(7) If the board determines that a proposed rule is of the type described in subsection (1)(c) of this section, and the proposed rule would require new or increased standards for forest practices, as part of or in addition to the economic and fiscal impact statement required by ORS 183.335 (2)(b)(E), the board shall, prior to the close of the public comment period, prepare and make available to the public a comprehensive analysis of the economic impact of the proposed rule. The analysis shall include, but is not limited to:
(a) An estimate of the potential change in timber harvest as a result of the rule;
(b) An estimate of the overall statewide economic impact, including a change in output, employment and income;
(c) An estimate of the total economic impact on the forest products industry and common school and county forest trust land revenues, both regionally and statewide; and
(d) Information derived from consultation with potentially affected landowners and timber owners and an assessment of the economic impact of the proposed rule under a wide variety of circumstances, including varying ownership sizes and the geographic location and terrain of a diverse subset of potentially affected forestland parcels.
(8) The provisions of this section do not apply to temporary rules adopted by the board.

SECTION 14. Section 8, chapter 565, Oregon Laws 1997, is amended to read:
{ + Sec. 8. + } { + (1) + } Sections { - 1 - } { + 3 + } to 6 { + , chapter 565, Oregon Laws 1997, + } { - of this Act - } are repealed on January 1, 2000. { +

(2) Sections 1 and 2, chapter 565, Oregon Laws 1997, are repealed when the State Board of Forestry adopts permanent rules implementing section 4 (4)(b) of this 1999 Act and the amendments to ORS 527.630 and 527.710 by sections 11 and 12 of this 1999 Act, or on January 1, 2000, whichever is later. + }

SECTION 15. { + On or before January 1, 2001, the State Department of Geology and Mineral Industries, State Forestry Department and the Department of Land Conservation and Development shall report to the Seventy-first Legislative Assembly on the implementation of sections 1 to 9 of this 1999 Act. The report shall include at a minimum:

(1) The results of the work of the State Department of Geology and Mineral Industries to identify and map further review areas under section 4 (4)(a) of this 1999 Act;

(2) Information about the pilot program to develop a model program for the mitigation of hazards and transfer of development rights pursuant to section 8 of this 1999 Act; and

(3) Recommendations for any specific changes necessary to the programs established pursuant to sections 1 to 7 of this 1999 Act. + }

SECTION 16. { + (1) Notwithstanding any other provision of law, in addition to any other amounts appropriated to the State Forestry Department, for the biennium beginning July 1, 1999, there is appropriated out of the General Fund $224,000 to the State Forestry Department for the purpose of carrying out the responsibilities of the State Forestry Department under section 4 of this 1999 Act and the amendments to ORS 527.630 and 527.710 by sections 11 and 12 of this 1999 Act.

(2) Notwithstanding any other provision of law, in addition to any other amounts appropriated to the State Department of Geology and Mineral Industries, for the biennium beginning July 1, 1999, there is appropriated out of the General Fund $247,745 to the State Department of Geology and Mineral Industries for the purpose of carrying out the responsibilities of the State Department of Geology and Mineral Industries under section 4 of this 1999 Act. + }

SECTION 17. { + In addition to and not in lieu of any other appropriation, there is appropriated to the Department of Land Conservation and Development, for the biennium beginning July 1, 1999, out of the General Fund, the amount of $50,000 for the purpose of carrying out the provisions of section 8 of this 1999 Act. + }

SECTION 18. { + (1) In addition to and not in lieu of any other appropriation, there is appropriated to the Emergency Board, for the biennium beginning July 1, 1999, out of the General Fund, the sum of $50,000 for allocation to the Department of Land Conservation and Development for the purpose of carrying out the provisions of this 1999 Act.

(2) If any of the moneys appropriated in subsection (1) of this section are not allocated by the Emergency Board prior to November 1, 2000, the remaining moneys on that date become available for any other purpose for which the Emergency Board lawfully may allocate funds. + }

SECTION 19. { + Section 8 of this 1999 Act is repealed on June 30, 2001. + }

Appendix 2: Glossary of Terms

Colluvial materials include soil and rock that have been moved by landslides, debris flows, rolling or falling, and are typically poorly sorted and loose.

Confined channels are stream valleys that are narrow (typically 5 to 200 feet) and surrounded by steep valley walls (slopes over 40 percent). These channels are more likely to be subject to debris flows than other stream channels.

Dam-break floods and ***migrating organic dams*** can have impacts similar to debris flows but are much less common. These features can impact larger, less steep, and less confined streams and rivers. These maps do not include dam-break flood or migrating organic dam hazard.

Debris fans can occur at the base of steep hillslopes and at the mouths of steep canyons. They form slopes of between 5 and 40 percent steepness. They contain an irregular assortment of soil, boulders, and sometimes logs (typically buried in the fan). It is not always possible to identify these dangerous locations on existing maps, so they are not always identified on debris flow hazard maps.

Debris flows in Oregon typically are initiated by landslides on steep slopes that quickly transform into semi-fluid masses of soil, rock, and other debris. They typically scour materials for a portion of their travel distance and move rapidly down steep hillslopes and confined channels**.**

Debris torrents are channelized debris flows. They typically contain a lot of large, woody debris. They can be distinguished from migrating organic dams by the height (above the channel) and severity of impacts around the channel.

Extreme rainfall periods are relatively short duration (about 12 to 48 hour) rainfall events that occur less than about once every ten years at any given location. Actual precipitation during this period may vary from at least 3 to at least 15 inches of rain, with climatically drier sites typically requiring less rainfall to initiate debris flows and torrents.

A ***landslide*** is the movement of a mass of soil, rock, or organic debris downslope. The typical landslide on steep forestlands begins as a relatively small and shallow feature, with typical dimensions of 3 feet in depth, 30 feet in width, and 40 feet in length with a relatively planar failure surface (same shape as the ground surface)

Rapidly moving landslides are landslides that can move faster than people can run. Velocities of debris flows may exceed 35 miles per hour.

Shallow-rapid landslides are typically small landslides that occur on steep slopes. The best available science indicates that these are the landslides most influenced by forest management practices. Depending on slope, landform, and channel conditions, shallow-rapid landslides may immediately spread out on the slope below the landslide, or may become rapidly moving landslides moving long distances down slopes and stream channels.

The ***Tyee Core Area*** is an area that studies indicate has higher susceptibility to rapidly moving landslides (Robison and other, 1999). It includes thick sandstone beds with few fractures. These sandstones weather rapidly, and concentrate water in the shallow soils, thus the higher landslide hazard.

Appendix 3: Silviculture and Landslides Report

SILVICULTURE AND LANDSLIDE SUSCEPTIBILITY

6-15-2001

Purpose: To correlate the increased occurrence of landslides after timber vegetation regrows on steep slopes and also to discuss options for forest management that mitigates this increased occurrence of landslides.

Objective: To better define, as current science and technical understanding allow, a definition of vegetative conditions where landslide risk is elevated after forest management practices (the period between timber harvesting and forest regrowth). This information may provide an opportunity to lessen, but not eliminate, the effects of forest removal on increasing landslide susceptibility.

Background: Changes in the roots and/or canopy of conifers in the forest are perceived to be the most likely vegetative (biologic) factors affecting the stability of steep slopes. Landslide-prone locations are typically steep (over about 70 percent slopes) with fairly shallow soil (averaging about three feet in thickness).

There are other processes that may be altered during timber harvest that may be responsible for the increased occurrence of landslides. For example, a change in the routing of subsurface flow could cause the increase in landslide occurrence. However, a change in water flow is considered the less likely factor, since landslides identified in the ODF 1996 Storm Impacts and Landslides study (Robison and others, 1999) found that soil disturbance was not identified with these landslides (exclusive of road-associated landslides).

Most landslide inventories including Robison and others (1999) have found that timber harvesting is associated with an increased occurrence of landslides on steep, landslide prone slopes. Higher landslide densities and erosion volumes were observed in forests that had been harvested during the previous nine years compared to forests older than 100 years (Robison and others 1999). The results of this study are similar to those of other studies (see pages 19 to 25 of the issue paper). Also, forests between the ages of 30 and 100 years had lower landslide densities and erosion volumes than mature forest stands.

Silviculture is the art and science of growing trees and it includes forest establishment, composition, and growth (Smith, 1962). In coastal Oregon, the most common silvicultural system is clearcut silviculture. In this silvicultural system, clearcut harvest is followed by site preparation by silvicultural chemicals or broadcast burning, planting conifer seedlings, and application of herbicides to control the growth of competing vegetation. Commercial and/or pre-commercial thinning to reduce stand density also occurs. Uneven aged management of forests in western Oregon is uncommon because Douglas-fir is an intolerant species and does not grow well in shade.

No applied research exists regarding the effect of alternative silvicultural practices on the occurrence of shallow-rapid landslides. This report uses information on the timing of landslide occurrence after timber harvest and the growth of roots and canopy of forests in western Oregon and forests similar to western Oregon to infer how harvesting affects landslide occurrence. These inferences are then used to hypothesize what vegetative factors might be the most important to affect the occurrence of landslides after timber harvest.

Questions: Several questions that related to information regarding the growth of conifer roots and canopy were discussed during meetings of the Silviculture sub-committee. The literature review included after this section lists references that were used to help address the questions.

- How does root biomass change over time after clearcutting (all species)?
- How are roots distributed by depth on steep slopes (coastal areas)?
- How does leaf area of conifers change over time after clearcutting?
- How does total root biomass change over time after partial cutting?
- How does leaf area of conifers change over time after partial cutting?
- What alternative silvicultural practices may reduce the time required to maximize total root biomass?
- What alternative silvicultural practices may reduce the time necessary for a conifer stand to reach maximum leaf area?
- Are roots less uniformly distributed in older stands?
- Does the re-growth of roots or of the forest canopy follow the observed pattern of increased landslide occurrence (highest landslide occurrence 0-9 years, lowest 30 to 100 years, then higher again after 100 years)? In other words, does this pattern of higher landslide occurrence correlate best with lower root biomass or canopy leaf area index?
- Are there other parameters that match the observed increase in landslide occurrence better than tree roots or forest canopy?
- Is there a difference in the biomass, diameter distribution or depth between woody and herbaceous roots?

Literature Review: A literature review was completed to obtain the available technical information regarding roots and canopy of a forest stand, especially the literature that is relevant to managed forests in western Oregon. The literature review is composed of 27 references on forest canopies and 39 references on the roots of forest trees. The following sections summarize the literature that is most relevant to the landslides and vegetation issues.

Forest Root Strength

The root system of a tree anchors into the soil, absorbs water and minerals, and stores carbohydrates (Eis, 1974). The configuration of the root system of a Douglas-fir is reached by the time the tree is only 10 years old (Eis, 1974). The biomass of the roots of conifers will increase from stand initiation to stem exclusion. The biomass of the fine roots of conifers peaks at canopy closure in both low- and high-productivity stands. The biomass of large roots continues to increase as the trees get older. At all stand ages, low-productivity stands had significantly more fine-root biomass than high-productivity stands (Vogt and others, 1987). This is probably because these sites require the trees to expend more effort in obtaining nutrients and moisture to survive. Fine roots made up seven percent of the total biomass of roots in an old growth forest in the H.J. Andrews Experimental Forest (Long, 1982).

After timber harvest, the roots of harvested trees begin to decay, while the roots of new trees and shrubs begin to occupy the site. Within 3-5 years after felling, the small roots of the harvested trees may lose over half their original tensile strength (O'Loughlin, 1974). Cedar roots last longer than Douglas-fir roots (O'Loughlin, 1974). Tree roots can graft, which will keep some roots alive after harvest, but this situation is generally uncommon (Eis, 1973). Seventy-five percent of Douglas-fir roots 0.4 inches or smaller in diameter were lost within 24 months after felling in coastal Douglas-fir and within 60 months after felling in Rocky Mountain Douglas-fir (Burroughs and Thomas, 1977). Larger roots take longer to decay. Ziemer (1981) found that forests harvested 3 years earlier contained about one-third of the root biomass of old-growth forests.

O'Loughlin and Ziemer (1982) state that "the accelerated incidence of landsliding between 3 and 10 years after forest removal (on steep slopes in Alaska, British Columbia, Oregon, Japan, Idaho and New Zealand), which coincides with the time after cutting when roots of smaller diameter have undergone advanced deterioration provides a strong indication that it is the smaller roots less than 20 mm [0.8 inches] in diameter that are most important to soil and slope stability." Note that in the ODF study no peak in landslide density was observed 3 to 6 years after harvesting as root strength theory would suggest (Robison and others, 1999). In only one study could data on this time lag be identified (O'Loughlin and Ziemer, 1982). It is possible that there are regional differences in root strength related delay in the increased occurrence of landslides, and perhaps there are also regional differences in the importance of forest roots.

In live trees, fine roots will die back during the dormant season. During the winter in western Oregon, large and statistically significant changes in the standing crop of fine roots occurred within short intervals and wet sites lost fewer roots to dieback than dry sites (Santantonio and Hermann, 1985). This may be important because storms occur during the winter when fine roots will have experience dieback. The spatial distribution of roots can be highly variable. Zeimer (1981) found tremendous variation in root biomass within and between different locations.

Roots can add strength to the soil by vertically anchoring through the soil mass into failures in the bedrock and by laterally tying the slope together across zones of weakness or instability (Ziemer and Swanston, 1977). Field measurements of soil with tree roots showed that soil strength increased as root biomass increased (Zeimer, 1981). Roots can also pull out (Zeimer, 1981). Most studies conclude that small roots (depending on the study, smaller than between 0.25 and 1 inch in diameter) are believed to be most important to soil and slope stability (O'Loughlin and Ziemer, 1982, Burroughs and Thomas, 1977, Wu and others, 1979).

To provide tensile strength to a soil, roots must be able to stretch across a failure surface. The strength added to the soil is the amount of tension in the root as it is stretched across the failure surface. Different sized roots or roots with different diameters will stretch different amounts in response to a given tension. Small diameter roots are more elastic and have a lower ultimate tension than roots with large diameters.

When small diameter roots stretch enough to reach ultimate tension, the large diameter roots have barely stretched at all and the tension in these roots remains very low. Conversely, when large diameter roots have stretched sufficiently to add considerable tension to the soil, all the smaller roots will have failed and will not be adding strength to the soil. Because small roots dominate in terms of number of roots, the maximum potential increase in soil strength attributed to roots occurs when the small roots approach ultimate tension. At this deflection, however, the large roots add very little to the increased strength due to the limited elongation of the large roots. Skaugset (1997) considers small roots to be less than about .25 inches in diameter.

Schmidt (1999) measured root characteristics at 41 sites in the Oregon Coast Range. He measured all roots, not just fine roots, and found the highest estimated soil cohesion attributed to root strength in three soil pits in natural forests. He measured attributes of roots from four tree species and eight shrub species, and developed soil strength relationships for each species. Eis (1974) found that the greatest number of roots that penetrate deeply into the soil in trees between 11 and 15 years old. Schmidt (1999) found few roots that penetrated into bedrock.

The average depth of roots in the Oregon Coast Range is the upper 1.5 to 2 feet of soil (Schmidt, 1999). Total soil strength attributed to roots measured in soil pits in the forest and adjacent to landslides has high variability even among soil pits in forests with similar stand ages. The tensile strength of roots varies by species. The individual roots of live brush were twice as strong as the same size conifer roots and the biomass of roots under 0.1 inches in diameter from harvested sites dominated by brush was 80 percent of biomass in an adjacent uncut forest (Ziemer, 1981).

Wet sites [sometimes landslide-prone] support different vegetation than more upland forest areas. Pierson (1977) found that salmonberry or sword fern were dominant understory species around landslide initiation sites in the Coast Range. The size distribution of rhizomes (underground stems similar in strength to roots) on forested sites dominated by salmonberry resembles the size distribution of roots from an uneven-aged stand of trees. After disturbance, salmonberry is often released and will continue to grow and could take over a site. The greatest biomass of salmonberry rhizomes occurred in 13- to 18-year-old clearcuts where no overstory trees were present. Salmonberry in alder stands were larger than those in conifer stands and on riparian sites (Tappeiner and others, 1991).

Red alder and shrubs develop fine roots faster than conifers. In dense stands of red alder, roots will very quickly (1 to 2 years) reoccupy the site and the roots may be deeper than other species (DeBell and others, 1994; Zavitkovski and Stevens, 1972). However, these species have a shorter life span. For example, red alder does not live longer than 80 years on average (DeBell and others, 1994), and alder stands may be replaced by salmonberry when they senesce rather than conifers.

Silviculture practices other than clearcut silviculture can affect roots. One might surmise that if the small trees in a stand were thinned, most of the root biomass would not be affected. The more trees that are thinned, the greater the impact on roots—even though it may be a temporary impact (Tappeiner, 2001). The lowest estimates of soil strength attributes to roots in one study were found in three soil pits in clearcuts where herbicides had been applied (Schmidt, 1999).

Forest Canopy and Water Relationships

The canopy of a forest is usually described by leaf area index (LAI), which is the ratio of the surface area of all leaves, needles, branches and bole above the ground to a unit area on the ground. During rainfall, the forest canopy stores moisture. Even when the storage of the canopy is full, water is stored for a short period of time. Megahan (1983) documents many changes in subsurface hydrology following harvesting and shows an average increase of 47 percent in maximum groundwater levels following clearcutting using helicopters and subsequent wildfire on granitic slopes in Idaho.

Even in the winter, trees can remove some water from the soil through transpiration. Evapotranspiration includes a combination of water stored on leaves re-evaporated to the atmosphere before it reaches the ground and water removed from the soil by the tree. Waring and others (1981) found lower evapotranspiration after forest removal, including winter months. Wu and others, (1977) found higher piezometric (soil pore water) levels in recently harvested areas 5 years after harvesting.

For broad-leaved forests, the LAI is calculated from one side of the leaf only, while the total leaf area surface is used in needle-leaved stands (Art and Marks, 1971). Leaf area is related to soil water balance (Grier and Running, 1977). Water storage in the canopy is proportional to the LAI. There is great variability in leaf area between species and sites, conifers have a higher leaf area index than hardwoods (Art and Marks, 1971), so they can store and re-evaporate more moisture. While red alder may recover roots biomass very quickly after disturbance, they have a low leaf area index during winter because they are deciduous (DeBell and others, 1994; Zavitkovski and Stevens, 1972). Wet, landslide-prone headwalls are more commonly occupied by salmonberry (a deciduous shrub) and alder (Pierson, 1977), so these sites may not experience the same water storage and transpiration effects as conifer-dominated sites.

Leaf area is highly variable. The variability in LAI is in part related to climate. Locations with mild climates and adequate moisture have the greatest potential LAI. Leaf area reaches a steady state (near maximum) early in succession (Grier and Running, 1977). The age when maximum LAI occurs corresponds roughly to when canopy closure occurs (when crowns of adjacent trees are overlapping). Canopy closure and maximum leaf area occurs at an age of 10 to 20 years after stand establishment depending on replanting, climate growth, and stand management. Older stands may experience reduced LAI through natural pruning (limbs blowing down) and leaf area also decreases as a stands becomes decadent (Gholz, 1982).

Herbicide application and/or slash burning, which are both used to reduce competition and aid conifer growth, result in temporary decreases in plant cover. Slash burning strongly influences successional trends (Dyrness, 1973). There is very little data on canopy regrowth after thinning or partial cutting. One might surmise that if small trees were thinned that the bulk of the leaf area would not be affected. The more trees that are thinned, the greater the impact on leaf area--at least a temporarily (Tappeiner, 2001).

Findings: The decay and subsequent re-growth of fine roots could explain the increased landslide occurrence frequently observed after timber harvesting. Lateral root strength is probably a more important factor than root strength at the base of landslides, at least in western Oregon. Basal root reinforcement may be relatively more important in other steep slope areas of the world. Total root tensile strength can be affected by species, time since disturbance, and "gaps" in the forest. Red alder and shrub species probably provide more rapid root recovery than do conifers, but probably do no reach the same total root mass as conifers. The fine roots of conifers recover to near maximum at canopy closure (10 to 20 years after harvesting); this time is somewhat dependent on stand management practices. Reforestation and early stand management practices that maintain as much of the root system of hardwoods and shrubs is prudent, in order to maintain as many roots as possible consistent with establishment of conifers.

The loss of canopy could also explain the increased landslide occurrence frequently observed after timber harvesting (however many of these landslide prone locations are covered by hardwoods and brush, so may have little canopy cover). Hardwoods and most shrubs have little winter leaf area index. Conifers, on the other hand, maintain most of their leaf area in the winter and also maintain some level of evapotranspiration in the winter (especially at lower elevations in the Coast Range where winters are milder). The time when conifers experience lower leaf area index (from 0 to between 10 and 20 years after stand establishment) also corresponds to the period of increased landslide occurrence observed in ground-based landslide inventories. Thus, it is possible that changes in the forest canopy may also be an important factor affecting the stability of steep slopes.

Based on this information, it is most likely a combination of reduced roots and reduced canopy that results in increased susceptibility to landslides. The fine roots and canopy of conifers seem to recover at about the same rate after timber harvesting. Therefore, canopy closure of conifers is probably the best measure of the end of any perceived "window of vulnerability."

Healthy, growing conifer forests at canopy closure (typically from between 10 and 20 years after stand re-establishment and until canopy openings begin to develop) should have the least susceptibility to landslides as compared to other forest covers. However, even in this optimum condition related to fine roots and the canopy, landslides will still occur. Conifer establishment and maintenance may be difficult on the locations most susceptible to landslides, since the water level and disturbance regime on these sites may provide more suitable habitat for red alder and salmonberry. Thinning to remove suppressed, dying and/or dead trees should have little effect on stability as long as ground disturbance is avoided. However, at least for sites covered by conifer, any removal of healthy vegetation is expected to have some negative effect on slope stability on steep, landslide-prone locations.

Reforestation in certain landslide prone locations, especially headwalls, may be more difficult than reforestation in an average location. These sites tend to be wet, prone to soil ravel, and prone to revegetation by shrubs and hardwoods. Additional actions may be required to successfully establish conifers on these locations, especially when maintenance of other vegetation is also desired. These actions can include: planting at high density of large plug seedlings, and site specific vegetation control with a backpack sprayer or a saw.

Research needs: Since applied research is lacking, there is a great need for research on managed steep-land forests. However, since landslide-producing storms are uncommon, such research is difficult, and results may not be available for decades. Nevertheless, it is prudent to be ready for such an event when it occurs, with study sites selected and vegetative characteristics sampled. To this end, a study plan, including data collection locations and vegetative sampling methods, is appropriate.

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Appendix 4: Debris Flow Impacts Study

Methods

The Debris Flow Impacts (DFI) Study was designed to assess factors contributing to debris flow/torrent impacts from rapidly moving landslides initiating on forestlands. Sites with varying impacts from debris flows and debris torrents have been selected for this study. A total of 18 impacted locations have been investigated thus far. Additional field data remains to be collected in a few of these locations. Also, the DFI Study is an ongoing study and additional study sites will likely be investigated in the future.

The DFI Study is based on the fact that physical slope and channel characteristics affect debris torrent hazard. More specifically, the following factors are hypothesized to increase rapidly moving landslide hazard:

- Initiating landslides that occur in, or directly adjacent to, channels;
- Fill failures (from roads, railroads, landings, or waste areas);
- Channels that have been incised into colluvium;
- Channels loaded with woody debris;
- Steep channel gradients;
- Moderately confined channels; and
- Debris fans (their presence indicates a high hazard);

And in addition, the following factors are hypothesized to decrease debris torrent hazard:

- Low channel gradient;
- Extremely constricted channels or channels with wide confinement;
- Sharp channel junction angles; and
- Alluvial fans (their presence is the result of fluvial process unrelated to debris torrents).

The DFI Study is examining these factors related to hazard and also the vulnerability of structures or roads. At each study site, the locations of structures and roads in relation to the locations of channels (debris torrents) and steep slopes (debris flows) were surveyed and tied into channel or slope profiles conducted along the debris flow/torrent path leading up to impact.

The level of impact at each site was recorded and damage to structures (or vehicles, in the case of Highway 38) resulting from debris flow/torrent impacts were placed into one of four categories.

1. Obliterated structures were incorporated into or completely buried by a debris torrent
2. Destroyed structures are unsafe and cannot be made livable again
3. Damaged structures have lost some structural integrity, but are repairable.
4. Inundated structures have mud or boulders in and around the house (lower velocity impact that, in some cases, was not repairable).

Discussion

Table 1 lists the average gradient of the channel 150 feet, 300 feet, and 500 feet before impact for all of the study sites. The type of event and amount of damage incurred during the event is listed as well. All but two of the channels average greater than 6% gradient for the last 300 feet before impact. This agrees with the Benda-Cundy model. The two exceptions are Woodson and Zahn Creek, both attributed to road fill failures. These debris torrents had traveled significant stretches of low gradient channel prior to impact, further than debris torrents initiated by typical shallow-rapid landslides within harvest units.

Table 1. Average gradient for the last 150 feet, 300 feet, and 500 feet of channel before impact

Name of Event	Type of Event	Avg. Gradient Last 150 feet Before Impact (%)	Avg. Gradient Last 300 feet Before Impact (%)	Avg. Gradient Last 500 feet Before Impact (%)	Structure Damage
Beers	Senate Bill 12 Appeal	4.4	5.5	9.8	N/A
Tri-Cities	Debris Torrent	7.3	9.3	10.0	inundated
Paint Barn	Debris Torrent	6.7	9.7	11.0	inundated
Smith River Grange	Debris Torrent	13.3	13.3	15.0	inundated
Dodson/Warrendale	Dam Break Flood	6.0	6.0	6.0	damaged
Erickson	Debris Torrent	10.0	10.7	13.6	damaged
Blacks	Debris Torrent	10.0	12.0	20.0	damaged
Mapleton School	Debris Torrent	40.0	26.7	44.0	damaged
Zahn Creek	Road Fill Failure	4.0	3.7	3.2	destroyed
Woodson	Railroad Fill Failure	4.7	4.0	3.8	destroyed
Hausmann	Debris Torrent	6.0	9.3	9.2	destroyed
Highway 38	Debris Torrent	17.5	28.4	23.6	destroyed
Rose	Debris Torrent	27.3	46.7	50.6	destroyed
Bones	Debris Torrent	43.3	50.0	65.6	destroyed
Rock Hubbard	Debris Torrent	15.3	18.6	21.0	obliterated
Neal Creek	Road Fill Related?	6.7	21.7	32.8	obliterated

Measurements of impact site geometry have been combined with measurements of channel confinement to create Figure 1, which shows impacted structures in relation to the point where the torrented stream channel loses confinement. The different types of events are represented with different symbols. Letters within those symbols are used to denote the level of impact and the occurrence of fatalities and serious bodily injuries, injuries requiring extended hospital treatment. The area in gray is currently considered by the Senate Bill 12 Interim Prohibition of Operations (IPO) to be in at significant risk of debris torrent impact.

The most severe debris torrent impacts (including all of the fatalities, injuries, and destroyed homes) associated with timber harvesting or natural shallow-rapid landslides occurred within 100 feet of a confined channel or within 110 feet of the channel at the loss of confinement. Note the location of the Rock Hubbard impact site was 1700 feet upstream from the loss of confinement and suffered extreme impact (obliteration). All of the fatalities, injuries, destroyed and damaged homes occurred within the IPO area with one exception (Woodson). The Woodson landslide was not associated with timber harvesting, so a prohibition of timber harvesting would not have affected its occurrence. It was attributed to a railroad fill that failed and caused a landslide dam, which subsequently catastrophically breached, and caused a debris torrent that destroyed an unoccupied mobile home. Figure 1 illustrates another key point. Most of the impacted structures are directly aligned with the direction of the channel at the loss of confinement. All but two of the impacted structures were within 12° of the channel alignment at the loss of confinement.

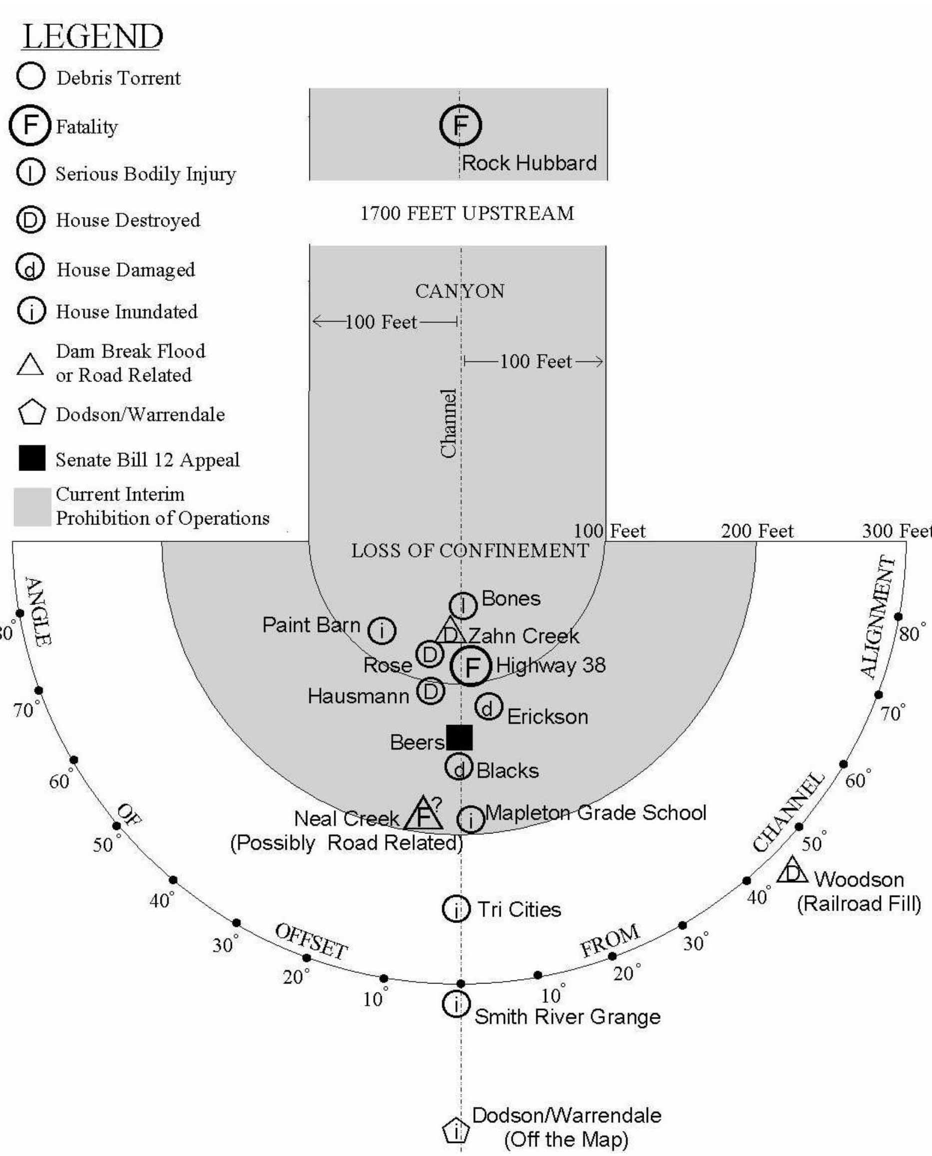

Figure 1. Plot of debris torrent impacted structures in relation to the point where the delivering channel lost confinement.

Channel junction angles and slope steepness generated using 10-meter digital elevation model (DEM) appear to have little relationship to actual field conditions. Thus, a hypothetical drawing was constructed.

Figure 1 illustrates the possible difference in debris flow hazard and risk that operations in the same watershed could face. Figure 2 shows two operations, Operation A and Operation B, in light gray. High hazard areas within the basin are shown in dark gray. Operation A clearly poses a higher debris torrent risk to the home than Operation B, since it contains a greater acreage of high landslide hazard locations, and also because of the lack of sharp junction angles.

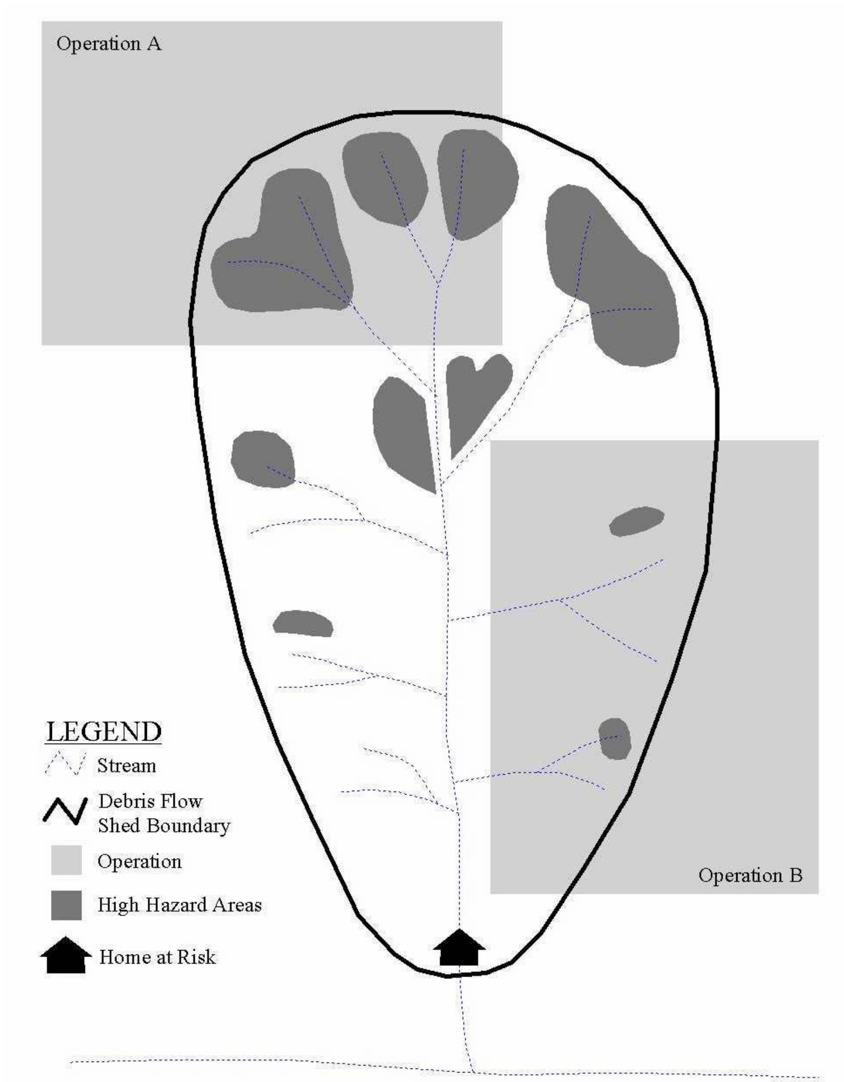

Figure 2. Typical scenarios for high (operation A) and low (operation B) hazard and risk to occupants of home.

Findings

1. The closer the home or road is to a debris torrent-prone stream channel's loss of confinement, the more likely it will experience severe impacts. Homes located in a canyon are likely to experience the most severe impacts and pose a great risk to human life. Homes located within 110 feet of the channel at the loss of confinement and within 12° of the channel alignment are also likely to experience the most severe impacts and pose the greatest risk to occupants.

2. Steeper gradients in the last 300 feet of channel before impact tend to produce more severe impacts.

3. Landslides associated with roads, especially large fills, result in debris torrents that move further than landslides associated with timber harvesting (down lower gradient streams and further from channel confinement.

Plan for Additional Work

The DFI Study will continue to gather data and refine the concepts illustrated in Figures 1 and 2. Determining the contributions of critical factors like channel gradient, channel confinement, and impact site geometry to risk will help determine an appropriate level of regulation and mitigation. One focus of this future work will be field determination of junction angle. This information will be compared with DEM junction angles, and with level of impacts.

Appendix 5: Technical Review of Issue Paper

Expert Reviewers (in addition to those on project team):

Dr. Lee Benda, Research Geomorphologist, Earth Systems Institute, Seattle, Washington

Dr. William Dietrich, Professor and Chair, Department of Earth and Planetary Sciences, University of California at Berkeley

Dr. Richard Iverson, Research Hydrologist, Cascades Volcanic Observatory, US Geological Survey, Vancouver, WA

Dr. Walter Megahan, Principal Research Scientist, National Council for Air and Stream Improvement, Port Townsend, WA

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Appendix 6: Economic Effects Examples

EXAMPLES OF HARVESTS DENIED LANDOWNERS DUE TO INTERIM LANDSLIDE RULES: WHAT DOES IT COST?

As of early April 2001, a total of 786 acres of land in Oregon have been left unharvested because of the interim prohibition of harvesting. These represent only a portion of the lands that would be affected over time under the provisions of Senate Bill 1211. Many landowners have stopped submitting notifications for operations when they know approval for operating on these lands will not be granted. Other landowners are unaware that they will not be able to harvest certain areas until the time they decide to plan a harvest.

1) DAVIDSON INDUSTRIES, BEERS TRACT, MAPLETON

Davidson Industries is a small, 4th generation, family-owned company based in Mapleton with about 20,000 acres of forest ownership and a mill. Their harvest scheme plans for a 70-year conifer rotation. With about 10% of the land now in riparian and other set-asides, more set-asides like landslide rules are affecting their ability to maintain rotation age, and continues to erode their ability to stay in business for another 50 years.

The Beers Tract has a 58-acre logging unit of which 25 acres was denied permission to harvest under the interim landslide rules. The 25 acres is a contiguous area of steep ground on a west slope facing a stream. Fifteen hundred feet downstream from the nearest edge of the denied unit is a house on an old debris fan.

On the 25 acre denied area is 524 MBF of mostly 100-year-old Douglas-fir, including 40 MBF of saw-log alder.

The standing value of this timber is conservatively $220,000. Standing value is the log price at a mill minus logging costs and harvest taxes, or what a buyer would pay for the timber as it stands.

The house and its property have a value of about $200,000. Cost to move the house off the debris fan is at least $50,000.

2) WILLIAM A. MCKINNIE TRACT, ELKTON

William McKinnie owns approximately 35 acres of timberland about 6 miles west of Elkton. The property is a steep, long, narrow piece that borders Highway 38 for close to one-half mile.

Of the 35 acres, about 15 acres have merchantable timber. The stand is primarily moderately stocked Douglas-fir, with about two-thirds of the volume in 40-year-old timber and the remaining in older residual timber. There is a cruised volume of 230 MBF.

The estimated value of the standing timber today is $80,000. In 1997, when Mr. McKinnie submitted a notification of operations and was unable to harvest under the Senate Bill 1211 interim prohibition, the estimated value of the standing timber was $115,000.

The terrain on 28 acres is very steep down to the highway with some rocky bluffs. Seven acres on top is flatter and is in a younger Douglas-fir plantation.

Mr. McKinnie can be characterized as a small woodland owner. He owns two other tracts for a total forest ownership, including this Elkton tract, of 261 acres. The timber on the other tracts is in non-merchantable younger plantations. He says, "virtually all the merchantable timber I own is on the Elkton property, I have a heck of a lot of my assets tied up in that timber."

"I would be happy to sell or trade this property to the State."