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A workshop on
SHORELINE MANAGEMENT AND STABILIZATION USING VEGETATION

COASTAL TRAINING PROGRAM Washington
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Tree Removal on Steep Slopes of Puget Sound Shorelines

The mechanical and hydrogeological benefits which trees and other vegetation provide to maintain slope stability and reduce erosion are well documented. Most of the wooded bluffs rimming Puget Sound are in a delicate equilibrium. For example, natural events such as an unusually intense winter rainstorm or human activities such as a concentration of upland runoff or careless logging on the bluff can reduce stability, even trigger landslides. As a planner or permitting agency official, what are your responsibilities regarding tree cutting? Given that there may be downslope impacts, possibly serious hazards to homes or public facilities, do you make decisions regarding tree cutting and/or removal? If so, remember the admonition to physicians: "First, do no harm."

Let's assume that trees have already been cut and downslope residents voice concerns about effects on bank stability. Some questions that may arise:

- Was the cutting authorized by your agency or another agency (e.g., DNR) that has jurisdiction?
- Who owns the land? Property side lines on waterfront/view lots are commonly skewed (Fig. 1). Property boundaries on the face of a bluff are commonly unmarked or inaccessible.
- Who cut the trees or hired the cutter? Timber trespass is not uncommon in such settings. Has a timber trespass occurred?

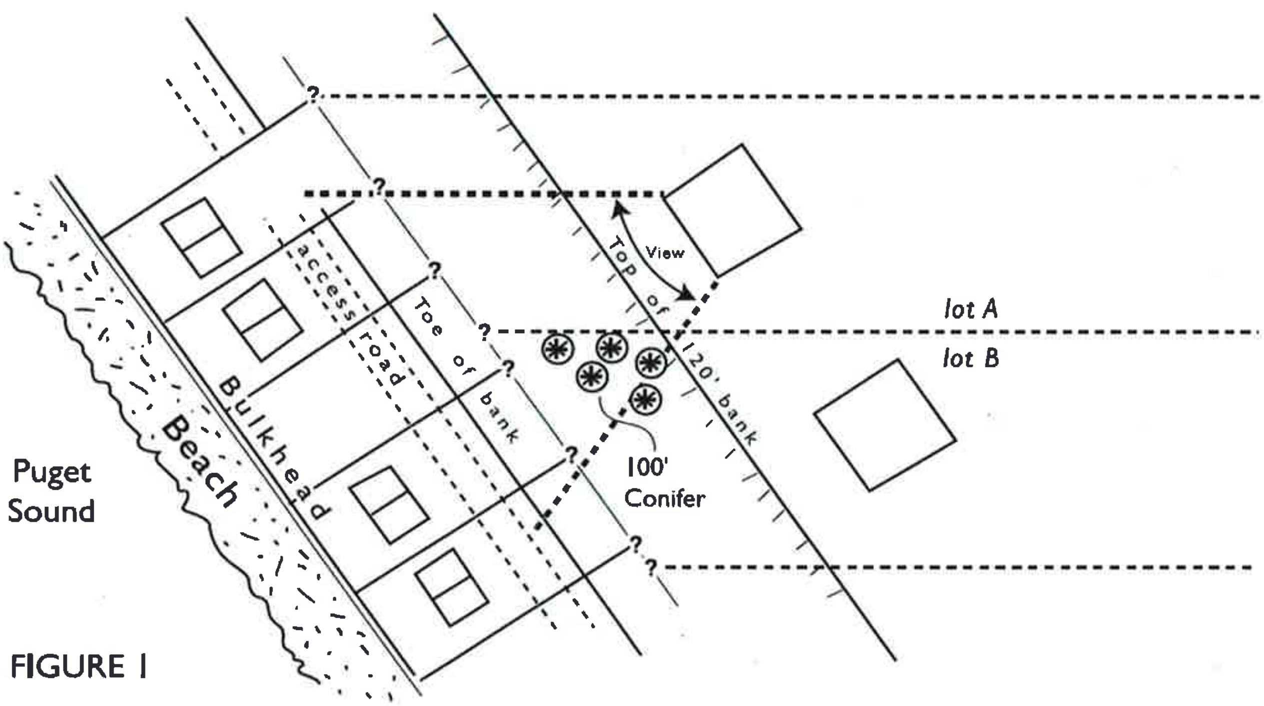


FIGURE 1

Figure 1. Sketch shows a typical scenario for development along shoreline bluffs. Note angle between lot side lines and edge of bank. Trees on lot B partially obscure the view from lot A, a setting ripe for timber trespass and/or legal squabbles. (Skewed property lines where there are no beach homes below can also complicate matters. In cases where wave erosion is at the toe of the bluff, a bulkhead fronting property B would mostly protect the home on lot A.)

Property ownership and cutting responsibility questions are basic to questions of log removal/leave and slope rehabilitation/replanting. As our main focal point here is on removal, an obvious question arises: Who pays for it? A property owner who cuts his or her own trees (after obtaining necessary permits, if any) is obviously responsible for such decisions. What about the rather common situation in such settings of 'timber trespass"? In at least some situations the owner is entitled to triple damages from the illegal cutter. Will the property owner allow access to the site for removal of the downed trees? If so, will that increase his or her liability for accidents or some future slide from their property? Such legal aspects of the problem are not trivial. Economics, including potential liability, may decide what (if anything) is done regarding tree removal, slope rehabilitation, and revegetation.

Upon what can 'damages" for trespass be based? The value of a tree for lumber can be calculated rather precisely on the basis of market factors such as species, size, cost to reach market, and current price. What about aesthetic value? (Some arborists and/or real estate professionals may be able to offer an estimate of the impact of the loss of the trees on property value.) The value of an individual tree or group of trees in relation to their role in maintaining slope stability is even more difficult to quantify, but it is often a significant consideration.

Let's assume that the trees were cut with city or county permission. Assume that the loss of trees will have some detrimental effect on slope stability, both immediately (precipitation interception, transpiration) and long term (loss of root/soil reinforcement, anchoring over time). Assume that the potential for any damage resulting from the instability (e.g., landslides) will be increased by the presence of large woody debris left on the slope. As the planner in the Permit Center who signed off on the cutting, should you insist on removal of the cut trees? (Hint: This slope may slide anyway, whether the logs are removed or not.)

As mentioned, the loss of mature or at least well-established trees has a significant effect on the stability of already marginal slopes. Soil disturbance and the further loss of young trees and brush, as well as the forest floor duff and litter, can further degrade stability. Log removal efforts can seriously disrupt shallow soils and such ground cover. Thus we are faced with two major options: leave the trees where they fell or remove them. Either choice can impact slope stability and legal liability. Logs can be removed with little or no further disturbance of soil and ground cover by what loggers and commercial foresters call "full suspension" techniques.

Logs are lifted, not dragged. This requires specialized heavy equipment both at the top and bottom of a slope (or at least a strong "block" or pulley with a massive anchor at one end). Full suspension can also be achieved by balloons or large helicopters. All such techniques are very expensive and/or impractical or impossible to use in most populated shoreline bluff settings. The 'reach' of a crane from the top or from the base of a bluff is limited, even where such sites are accessible; they are almost useless on bluffs in the 150- to 300-ft range.

Horse logging can minimize soil and underbrush disturbance, but cannot be done on slopes as steep as most of our shoreline bluffs. Tractors and excavators need roads on such slopes, and the logs still must be dragged to the road. Also, the roads themselves leave unstable slopes as well as concentrate storm runoff long after the logging is complete. Thus by process of elimination, we are left with hand labor for removing large woody debris from most steep coastal bluffs.

Assuming that hand labor is the only practical option for removal of downed timber from steep (35+ degree) slopes, let's consider its limitations.

- It is dangerous, hard work, even for the experienced.
- Thus, experienced help can be expensive.
- Amateur do-it-yourself help can be more expensive (i.e., medical, liability)
- There is a limit to the size of material that can be handled (excluding help from gravity, which we are trying to avoid)

Some ways we can minimize these limitations are:

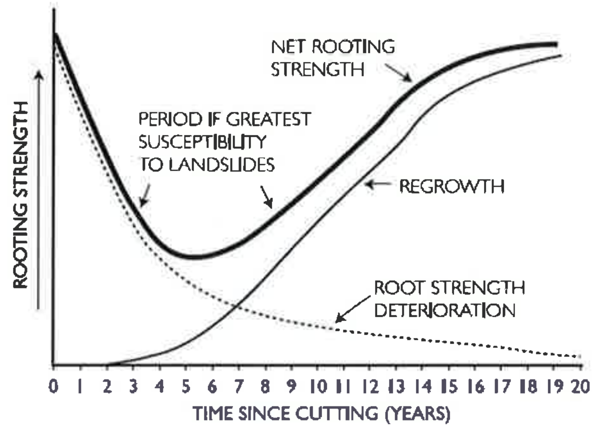
- If there is no hazard (people, structures) below, reconsider. Maybe the logs should be left in place; let nature take its course (i.e., rot and gravity)
- Leave wood in contact with the ground, if possible, to facilitate rotting.
- Work when spring slide hazard is past; remove wood in early fall.
- If a log is oriented within 20 degrees or so of perpendicular to the slope and is supported by a sprouting stump at both ends, leave it.
- Cut (and split?) a log into sizes that can be manhandled.
- Leave tops and limbs smaller than 3- to 4-in. diameter scattered on the slope as ground cover.
- Do not pile tops/limbs, as piles can prevent regrowth (natural or planted) and smother native brush.

In precarious areas directly above a residence, hazards can be minimized by common-sense techniques such as tying a downed tree to a stump before cutting it into logs. Temporary 'cyclone fences' can be strung between standing trees above the downslope home. Experienced woodsmen (for example, cedar cutters) can move wood in ingenious ways with little equipment. Don't try to "fine tune" their plan; every situation of trees, topography, and potential hazard is unique. Perhaps the best conditional constraint would be that no additional disturbance to the slope should occur.

Before ordering removal of large downed trees on a steep slope, the planner/permit official might want to check with their legal counsel. What is at hazard downslope? Do homeowners at the base of the bluff understand the options and potential hazards? For example, a "cartwheel" of firewood from a 3- to 4-ft fir can become lethal if it starts rolling on a steep slope. Who is liable? The wood cutter? The property owner? The agency that ordered or approved the removal? All of the above? (An industrial or commercial downslope property owner might want to make their own plans regarding timber cutting/log removal.)

What about stumps? A stump and its rootball, *if mobilized* into a shallow fast-moving slide (debris avalanche), can add to the future damage potential of the mud and smaller debris. However, removing stumps *will increase* the likelihood of such events. As the roots of many stumps rot, their ability to provide reinforcement and anchoring of the soil/vegetation mat decreases. However, they may still provide that critical role, albeit to a decreasing extent over time, while new trees are getting established. (See figure 2) Generally, stumps of cut trees should not be removed.

FIGURE 2. CONCEPTUAL GRAPH INDICATING ROOT STRENGTH DETERIORATION AFTER CUTTING (R. SIDLE, 1984)



Special mention is warranted for stumps that sprout, thus keeping the stump alive and its roots functioning. Species such as maple, willow, and madrone usually sprout and, after several years, may provide the same slope stabilizing benefits as the standing tree. It is not unusual to see cut-over slopes slide except for the area at and below a single sprouted maple stump. Also, removing a stump on a bluff via hand labor is slow and expensive and creates a bare patch subject to erosion and increased infiltration. Except in isolated instances where a stump is an obvious hazard, they should be left.

If you need to remove large (1-ft+) trees from an area of steep ground (35+ degrees) where property and lives below could be at stake, get a pro. The passing 'blow-hard' who can shrug and walk away from his self-created "accident" won't do. Get a responsible expert (one who is licensed, bonded). That person should be able to tell if a particular site is a 'piece of cake' or will require much finesse. If the hazard potential is great, you might want a second opinion. As a public official, with your signature on the application, carefully exploring all options may save you and your agency later grief and expense.

Mitigation of damage to the slope from tree cutting and removal of debris should be a routine condition of permitting tree removals. Mitigation specifications should reduce both short- and long-term stability and erosion impacts which are likely to occur as a result of tree removal. Measures such as revegetation with suitable native species are often effective if an agency requires adequate monitoring and project maintenance during the establishment period (3-5 years). Vegetative buffers at the crest of the slope, as well as drainage controls of upland and slope surface-water run-off are also valuable mitigation tools.

Cutting of trees and removal of large woody debris from steep slopes can impact slope stability and have long-term legal ramifications for landowners and permitting agencies. Caution and common sense should be exercised in managing steep, often unstable, marine slopes.

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TREES, SOILS, GEOLOGY, AND SLOPE STABILITY

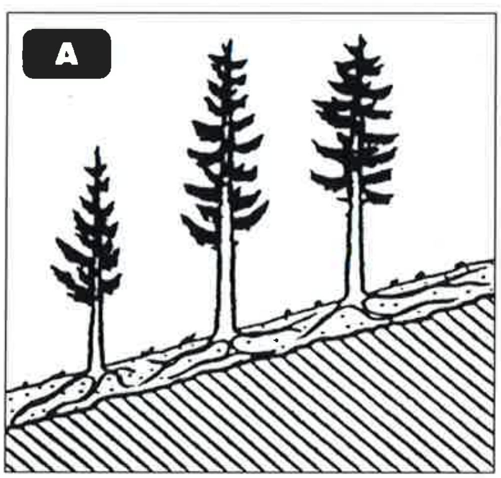
The following drawings and narratives are provided as a very simplified representation of how trees may influence slope stability on Puget Sound marine shorelines. They illustrate several generalized combinations of soil depth, stratigraphy, and tree rooting. The degree to which trees may influence stability on a given slope is a complex function of various specific, interacting physical, biotic, and human-related factors.

Physical factors include slope geometry and gradient, geologic materials, stratigraphy, hydrology, and the local effects of shore processes. Climatic variability can alter the dynamic equilibrium of a slope in significant ways.

The species mix of trees as well as their spacing, age, vigor and health, influence how effectively trees can stabilize slopes. The successional stage and complexity of the associated plant community can be a significant factor. The role of associated vegetation, though significant, in effecting hydrologic conditions, soil formation, and other factors which may influence erosion rates and slope stability is not addressed here.

Forested marine slopes are often barely stable, have adjusted to the various forces acting on them and have developed a delicate equilibrium. They are sensitive to alterations such as view clearing and tree removal, as well as upland site development such as lot clearing and grading. They may also be highly sensitive to cumulative upslope disturbance and local watershed modifications which effect slope hydrology. Disturbances such as logging, roadbuilding, and urbanization in developing watersheds can significantly alter conditions and upset the dynamic equilibrium of slopes, thereby indirectly causing increased landslide activity on previously stable slopes.

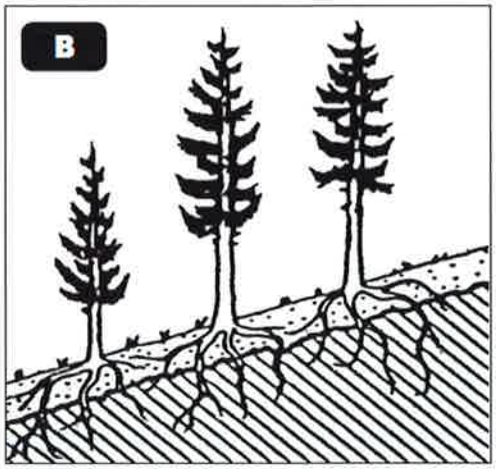
It should be emphasized that the following examples are greatly simplified when compared to actual conditions found on Puget Sound shorelines. For example; our shorelines are often steeper and the subsoils (geologic parent materials) are complex, resulting in erratic concentrations of groundwater, which complicate slope stability assessments.



Type A

Characterized by shallow (less than 3 feet) soils overlaying parent material (competent rock, glacial till, dense silt or clay) which resists root penetration. Surface soils are fully reinforced with tree roots. Lateral rooting, though shallow, often resists slope failures if tree density and distribution is adequate to provide an interconnected root-web matrix. Rooting is plate-like. Roots are at failure plane. Subject to rapid, shallow slides during extreme rain-on-snow events.

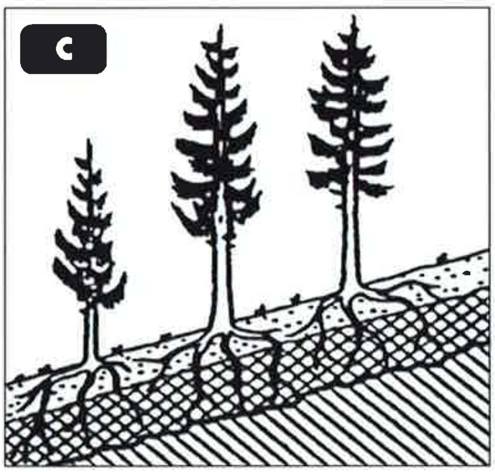
Stabilizing effect of roots: Moderate if not compromised. Tends to become rapidly unstable when disturbed, or subjected to increased hydrological influences. Anchoring - minor. Soil cohesion - high.



Type B

Characterized by shallow (less than 3 feet) soils overlaying parent material (dense sand, glacial till, etc.) which allows significant root penetration. Degree of anchoring into parent material by roots is dependent on the nature of the fractures in the parent material and the predominant tree species. Roots intersect potential failure plane, providing shear resistance.

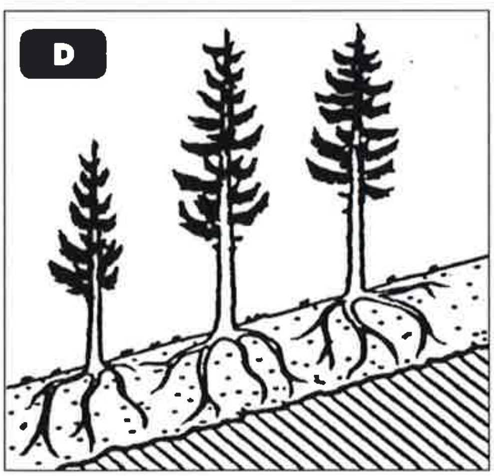
Stabilizing effect of roots: High. Individual trees are stable without a significant dependence on adjacent trees. Both anchoring and soil cohesion benefits are high.



Type C

Characterized by deeper soils (3-12 feet) with a non-distinct transition zone in which soil shear strength increases with depth. Assumptions include: (1) transition zone functions as a drainage moderator, allowing a concentration of groundwater and increased pore-water pressure; (2) failure plane passes through the transition zone; (3) soil zone is more easily penetrated and permeated by roots than in B, above. (Example: sandy loam over loose till over compacted till.)

Stabilizing effect of roots: Anchoring - high.
Soil Cohesion - high.



Type D

Characterized by deep soils where both the failure plane and the soils are deeper than the root zone. The actual depth of the soil for this condition to occur depends on root morphology (depth, spread, etc.) of the particular tree species on the slope. For example, on a slope where Red alder predominates, a relatively shallower soil depth would exhibit Type D conditions, while on a slope forested by Douglas-fir the stabilizing effects would be significantly greater for the same depth.

Stabilizing effect of roots: Anchoring - minor.
Soil Cohesion - moderate.

Illustrations adapted from: Vegetation Influences on Debris Slide Occurrences on Steep Slopes in Japan, Y. Tsukamota and O. Kasakobe. 1984

Prepared for Coastal Training Program by Elliott Menashe (www.greenbeltconsulting.com) 2004

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Value, Benefits and Limitations of Vegetation in Reducing Erosion

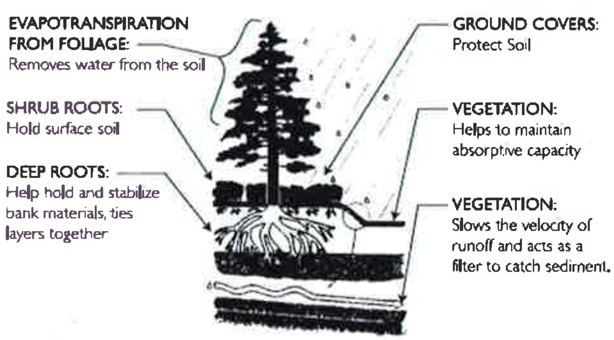
Trees, shrubs, and groundcovers can maintain slopes and reduce erosion from surface water, shallow groundwater and, to some extent, coastal processes. Evergreen trees and other vegetation are most valuable and able to protect soil and remove water during the winter months when deciduous plants are dormant. A diverse mix of both evergreen and deciduous plants provides the greatest protection.

Plants can also have value as sight and sound barriers, discourage access to hazardous areas, and define space in a yard. Native plants enhance wildlife habitat by providing nesting and hiding cover, food, and safe travel corridors. Once established, native plants require little maintenance or care. Species should be chosen for their ease of establishment, adaptability, usefulness, and availability.

Extensive lawns, especially in the vicinity of the bank crest, should be avoided because grass tends to increase surface-water sheetflow during wet conditions when soils are saturated. Low-growing evergreen or perennial plants should be established on the upper crest of the bank.

THE VALUE OF VEGETATION IN STABILIZING SLOPES

FIGURE 1. ROLE OF VEGETATION IN REDUCING EROSION AND STABILIZING SLOPES. (MENASHE, 1993)

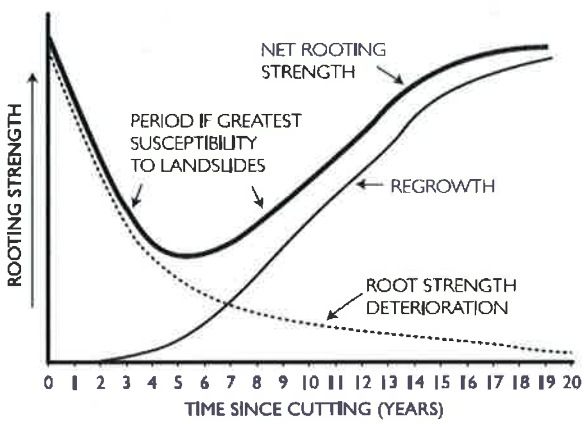


1. Foliage intercepts rainfall, causing absorptive and evaporative losses that reduce surface water runoff and erosion.
2. Evergreen trees and shrubs continue the metabolic activity known as evapo-transpiration, which extracts moisture from the soil, throughout the year. As logging or clearing occurs, water table levels rise, and soils remain saturated for longer periods, reducing soil cohesion and increasing the rate of land slides.
3. Roots reinforce the soil, increasing lateral soil sheer strength and cohesion during saturated conditions. Many slopes can persist beyond their angle of repose and remain stable as a result of the complex root networks within soil blocks.
4. Tree roots anchor soil strata vertically and laterally by means of large-diameter structural roots. These roots may extend well beyond the tree's canopy or crown.
5. Roots, especially the fine feeder roots of trees, shrubs and groundcovers, bind soil particles at the ground surface, reducing their susceptibility to surface erosion and slumpage during saturated soil conditions.
6. Large trees can arrest, retard, or reduce the severity and extent of failures by buttressing a slope. This works in much the same way as retaining walls. In the case of trees, though, the system is to some extent self-repairing, and it becomes progressively stronger over time, whereas engineering structures are strongest when installed and become progressively weaker over time. Obviously, planted trees need adequate time to develop root systems and become effective in stabilizing slopes.

LIMITATIONS OF VEGETATION

The limitations of vegetation in preventing, reducing or arresting slope failures and erosion is often due to previous land management practices such as logging, topographic alterations, increased or channelized surface water flow, and wholesale clearing. Once initiated, slope failures require an expenditure of time, effort, critical planning and money to stabilize them successfully. The use of vegetation in particular requires foresight and several years of monitoring and maintenance until plants are established and effective. Establishment can take up to three years. It can take up to 15 years for shrubby vegetation to develop the values discussed above, even longer for trees to reach sufficient stature to be effective. The impacts of tree cutting on steep slopes can take several years to become apparent, as illustrated in figure 2.

FIGURE 2. CONCEPTUAL GRAPH INDICATING ROOT STRENGTH DETERIORATION AFTER CUTTING (R. SIDLE, 1984)



Landowners need to be aware that not all vegetation provides effective erosion control. Just because it is green does not necessarily mean it works. Such common species as Himalayan blackberry, horsetails, English ivy, and red alder are often present on disturbed slopes and have limited erosion control value. Blackberry and ivy, in particular, tend to discourage more desirable vegetation from becoming established.

In some situations a combination of geotechnical engineering and vegetative techniques are required to assure a practical solution to slope problems. The best time to employ inexpensive relatively vegetative means is before severe failures occur. Note: It should be clearly understood that unusually harsh climatic conditions prior to full development of a vegetative root matrix could result in failure or partial failure of such a slope stabilization system. Landscape contractors should have an understanding of the processes affecting slopes, techniques to be employed to ensure success, and the potential hazards of working on steep slopes in vulnerable areas.

There are several situations where vegetation is relatively or completely ineffective in protecting a slope from failure. These include: (1) lower banks subject to wave attack; (2) areas of deep-seated geologic instability; (3) bluffs near vertical; and (4) unstable areas too wet or dry for vegetation to become established.

RECOMMENDATIONS

Plantings in areas that have not recently been subjected to slope failures are a wise investment. Preventive measures, employed before serious problems occur, are relatively inexpensive. Bear in mind that plantings of more desirable species to replace existing species such as red alder should be well established (2-3 years) before alders are removed, in order to maintain adequate soil-binding benefits within the effective root zone (ERZ) of the cut trees. The ERZ can be approximated as a one-foot radius of lateral root extent for every inch of diameter of the tree's trunk. Preparatory to planting, alders (as well as cherry) can be thinned to a spacing that will not compromise slope integrity during the establishment period. Tree cutting on slopes without replanting can have serious future consequences as illustrated in figure 2.

Proper selection of shrub and tree species for position on the slope will minimize view maintenance requirements while greatly improving slope stability. Care should be taken in selecting species that thrive under site-specific conditions found locally on the slope. These include soil moisture, light/shade, and rooting type.