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Field Guide for

Tree Risk Assessments and Hazard Tree Mitigation on Developed Recreation Sites, Worksites, and Road Systems

in Oregon and Washington Forests

Field Guide for Tree Risk Assessments and Hazard Tree Mitigation on Developed Recreation Sites, Worksites, and Road Systems in Oregon and Washington Forests

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Cover photo: A Douglas-fir in a campground that failed from laminated root rot.

Title page photo: A mitigated hazard tree with extensive internal decay and a conk of *Phaeolus schweinitzii.*

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The editors dedicate this guide to Gregory Filip for his leadership in the field of hazard tree management.

Dr. Greg Filip sharing his hazard tree expertise.

This field guide outlines the steps for a tree risk assessment program. Some information, particularly in chapter 4, is specific to forests in Oregon and Washington; the appendixes also contain tree and pathogen profiles for species and diseases common to that region. The remainder of the guide—including the prioritization process for determining where and when to conduct tree risk assessments, two tiers of surveys, identifying potential failure zone and impact potential, methods for documenting survey results, recommended mitigation options, and guidance on large-scale disturbances—can be applied elsewhere. These recommendations are based on the best available science, previous field guides, and the collective expertise and experience of the authors. When adopting any part of the tree risk assessment program outlined within this guide, use locally or regionally specific tree defects and associated failure potentials.

Acknowledgments

The authors thank Gregory Filip for leading the effort to write the previous guides for hazard trees (Filip et al. 2013) and danger trees (Filip et al. 2016) for Oregon and Washington which served as the foundation for this guide. We also thank Bob Harvey and Paul Hessburg for the 1992 guide that served as a template to the Filip guides and provided some content for this guidebook. The authors thank Craig Leech, Alan Kanaskie, and Paul Ries for developing a tiered survey and training system for Oregon State Parks that inspired parts of this guide.

Special thanks go to Nicole Lagioia, Rithy Bein, Barbara Garcia, Ken Kitrell, and Lisa Ball for their insightful contributions in developing this field guide and the program it outlines. We would like to thank the following people for their feedback and review of this guide relevant to their program or specialty: Andrea Lyons, Joe Doerr, Barbara Webb, and Aiden Forsi.

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INTRODUCTION

Introduction

Trees contribute to the beauty, enjoyment, and ecosystem functions of recreation sites, forest scenic routes, and viewpoints. Exposure to pathogens, insects, weather, fire, and a changing climate all influence forest conditions; however, these same factors can cause structural instability, damage, and mortality of forest trees. Structurally unstable trees or tree parts may fail and cause injury to people or damage to property if located within developed sites, along roadways, or near active worksites.

Recreating and working in forested areas exposes people and property to natural forest conditions that can potentially cause harm. This field guide provides a comprehensive methodology to assess the potential risks that trees can pose and recommends risk mitigation options to reduce the hazards with an emphasis on native forest trees in Oregon and Washington.

This field guide presents a tree risk assessment program that minimizes risk from potential tree failures. It is intended for forest recreation and resource managers, concessionaires, consultants, road maintenance engineers, incident management teams, and other specialists who assist in the management of developed sites, roads, and worksites located within forested areas. It is important to note that parts of this field guide are informed by the International Society of Arboriculture's (ISA) "Tree Risk Assessment Manual" (Dunster et al. 2017). Professional, qualified arborists use a similar risk rating system developed by ISA to evaluate tree risk in areas that are generally more urban and developed than natural forests. Professional arborists may not customarily work in natural forest settings and may not be as familiar with the diseases and natural processes that occur there.

This field guide integrates and updates the "Field Guide for Hazard-Tree Identification and Mitigation on Developed Sites in Oregon and Washington Forests" (Filip et al. 2013) and the "Field Guide for Danger-Tree Identification and Response along Forest Roads and Work Sites in Oregon and Washington" (Filip et al. 2016), which were based on the 1992 guide "Long-Range Planning for Developed Sites in the Pacific Northwest: The Context of Hazard Tree Management" by Harvey and Hessburg (1992).

Campground and swimming area with dead lodgepole pines killed by mountain pine beetles.

This updated edition introduces a prioritization process to identify where tree risk assessments should be conducted, presents two tiers of survey options, details the steps for performing tree risk assessments, describes methods for documenting survey results, and offers recommendations for mitigation strategies. The objectives of this field guide are to present:

- Standards for tree risk assessments and evaluating tree hazards.
- A standard for what type of survey to conduct and how frequently areas should be surveyed.
- A prioritization system for determining when to survey and treat road systems, developed sites, administrative facilities, and worksites.
- A field aid for accurate identification of diseases, defects, and potential tree failure.
- A standard for recording, documenting, and archiving evaluations.
- Approaches to assessing large-scale mortality events, such as fires or bark beetle outbreaks.
- Considerations for long-term vegetation management plans for developed sites.

What Is a "Tree Risk Assessment"?

A tree risk assessment evaluates both the potential for failure by examining a tree's structural defects and the potential for impact by considering the amount of risk that tree failure may pose to people or property. Identification of a hazard does not necessarily mean there is a risk; it must threaten a specific target for a hazardous condition to exist. Risk arises when a tree or tree part has an impact potential and is within striking distance of people or property. Risk increases with the severity of tree defect (i.e., failure potential) and the potential for impact (i.e., impact potential) due to increased exposure or value of the target. Managers take action after they decide to reduce risk, especially when they deem the hazards unacceptable.

Tree risk assessments require a unique skill set that combines scientific knowledge, keen observational skills, risk management, and a thorough documentation process. A working knowledge of tree species and forest pathology, regular monitoring, and an intimate knowledge of local site conditions, coupled with a thorough, consistent, and scientifically based evaluation process, all contribute to a high-quality tree risk assessment process and hazard tree management program.

Definitions

For the purposes of this field guide the following definitions apply. The glossary also defines these and other terms.

Designated site—An agency-identified location where the public is directed to go, which may or may not be developed with facilities. Examples include designated dispersed camping areas and designated backcountry or wilderness campsites.

Developed site—A place that concentrates use and has facilities provided for visitors or employees. The term “facilities” may be used in either a broad or narrow context (e.g., administrative facilities, telecommunication sites, ranger stations, and recreation sites such as campgrounds, day-use sites, trailheads, and boat launches).

Exposure—The state of being vulnerable to damage or harm, regardless of outcome, by virtue of being in proximity to a potentially hazardous tree. The duration and frequency of exposure are used in determining the impact potential.

Failure potential—The likelihood of a tree or its parts breaking, falling, or collapsing. (Ratings are described in chapter 4.)

Failure zone—The area within which a tree or its parts will likely land in the event of failure.

Forest road—A transportation facility intended to support motor vehicle traffic wholly or partly within or adjacent to and serving public lands with jurisdiction by a federal or local government entity that is necessary for the protection, administration, and utilization of public lands and the use and development of its resources.

Hazard tree—A tree or its parts that pose a risk of injury or damage to people or property and exceeds the risk tolerance of the responsible manager. Hazard trees are sometimes referred to as “danger trees” in policy, Occupational Safety and Health Administration (OSHA) documents, and other field guides. For the purposes of this document, the two terms are interchangeable.

Hazard tree management—The reduction of risk posed by hazard trees with a program that includes prioritization, assessments, documentation, monitoring, and mitigation, while balancing risk with the benefits trees provide.

Impact potential—The likelihood that a tree or tree part could strike a target and the resulting damage that may occur. Impact potential is determined by evaluating both the level of exposure and the severity of possible damage or loss (consequences). (Ratings are described in chapter 3.)

Mitigation—The action taken to reduce risk of damage or injury, such as closing sites, closing roads, moving targets, removing the defective tree or parts, etc.

Occupancy—The frequency that a site is used by people for the intended or managed purpose.

Risk—The probability that harm or loss will occur if exposed to a hazard. In the context of hazard trees, risk is the combination of the probability of tree failure (failure potential) and the level of exposure and the severity of possible damage or loss (impact potential).

Target—People, property, or infrastructure that could be injured or damaged by failure of a tree or its parts.

Tree risk assessment—A systematic process used to identify and evaluate the threat a tree may pose to a given target.

Worksite—An area in the forest where work is actively occurring, generally temporary in nature, infrequent, and related to activities such as road construction, logging, planting, surveys, or infrastructure repair and maintenance.

Hazard Tree Management

Land managers and employers have responsibilities defined by their respective agencies, as well as Federal and State policies, to assess and reduce risks to visitors and employees. Appropriate agency policies should be followed while developing a tree risk assessment program.

Hazard tree management should focus primarily on providing safe access and use by reducing the risk of injury to people and damage to property. A secondary focus should be to enhance the long-term health of forest stands and the ecosystem services they provide. The key here is to strike a balance between minimizing risks in developed areas while maintaining a forest structure that provides an aesthetically pleasing user experience with the need to maintain diverse forest stands and resilient ecosystems that benefit the natural environment. Vegetation management planning (chapter 7) provides strategies to meet these long-term goals and desired future conditions.

However, even under the best of circumstances, and with the highest standard of care, tree failure predictions are imperfect. A manager's ability to predict tree failure is limited, and even more so when trying to predict the timing of failure. Additionally, in unusual situations, such as extreme weather events, it is possible for trees without significant defects to fail. In general, it is impossible to manage for all situations in which trees or their parts may fail. However, by using a systematic approach it is possible to effectively and efficiently use limited agency resources to significantly reduce the risk of injury to people and damage to property (fig. 1).

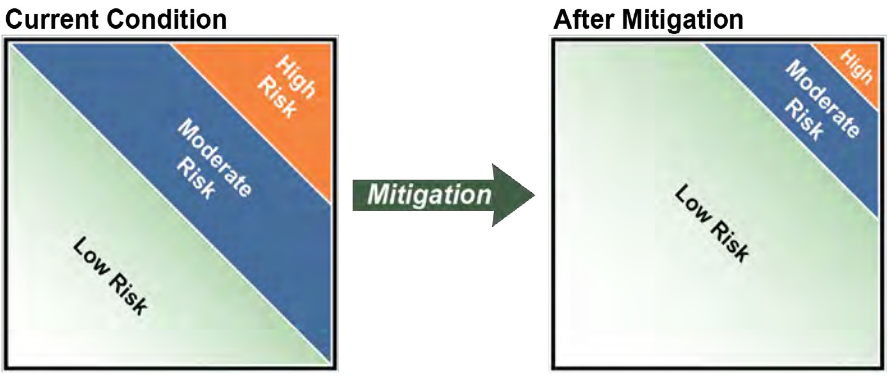


Figure 1—Proportion of trees in different risk categories before and after mitigation.

Six Steps for Tree Risk Assessments

A tree risk assessment program involves a systematic approach that includes a prioritization process for surveys and mitigation, assessing the likelihood of a tree or its parts striking a target, evaluating the exposure and potential for damage associated with specific targets, inspecting and rating a tree's structural defects and determining its failure potential, determining the risk rating of the tree, and documenting the risk assessment. This field guide incorporates these elements into six steps, outlined below and detailed in chapters 1–6.

Step 1—Develop the program of work by prioritizing where to survey and determining what type of survey to conduct—Office exercise (chapter 1)

Step 2—Determine potential failure zone of trees or tree parts (chapter 2)

Step 3—Determine the type of exposure and assign impact potential (chapter 3)

Step 4—Determine tree defects and assign a failure potential; reevaluate failure zone if defect is just part of a tree (chapter 4)

Step 5—Determine the tree's risk rating and mitigation options (chapter 5)

Step 6—Document the risk assessment and provide recommendations to the manager (chapter 6)

Step 1—Develop Programs of Work

A successful tree risk assessment program requires a systematic approach for prioritizing areas where tree risk assessments will be conducted and for determining the appropriate survey to conduct: a Tier 1 or Tier 2 survey (defined in chapter 1). As it is rarely possible to conduct comprehensive tree risk assessments across a broad landscape due to limited time and resources, the first step includes an office exercise with resource managers and tree risk assessors.

When prioritizing where to complete tree risk assessments, decision makers should consider workloads, budgets, values at risk, visitation, use, seasonality of use, duration of exposure, site history (including history of tree failures), specific local hazards, and timing of possible mitigation activities. These factors will determine the type and frequency of tree risk assessments. Coordinate with other specialists, such as wildlife and fisheries biologists, especially in areas with known sensitive species or restrictions (e.g., designated critical habitat for listed species or late-successional reserves), during step 1 (and step 6). Land managers should document their prioritization process.

Steps 2–5—Assign Risk Ratings

Once prioritization and survey type plans are confirmed and tree risk assessors begin to conduct risk assessments at prioritized sites, each tree in the area will be given a standard tree risk assessment incorporating two components:

- **Impact potential** is determined by evaluating both the level of exposure and the consequences of possible damage or loss. This portion of the rating is based on what is around the tree. This must incorporate the likelihood that a failure will strike a target (people or property), the likelihood of damage, and an estimated value of the target(s).

- **Failure potential** addresses the potential for tree or tree part failure within a specified time period, such as between inspection periods. This portion of the rating is based on the observed tree conditions.

The risk rating for each individual tree is determined by combining the values from the impact potential (scored 1–5) and failure potential (scored 1–5) components of the rating system. Thus, 9 risk ratings ranging from 2 to 10 are possible. Mitigation priorities are then based on the level of risk a tree may pose if left untreated. **Maximum risk ratings and mitigation actions will vary by project based on how targets are evaluated for impact potential.**

Step 6—Documentation and Recommendations

Documentation of tree risk assessments is key to communicating the level of risk a tree may pose and if mitigation is recommended. Record keeping will help to identify and communicate potential hazards before a failure occurs. Record keeping also demonstrates an agency's ongoing process of evaluating and managing the risk of injury to people and damage to property. Additionally, documenting where and when surveys have occurred will help prioritize where surveys should occur in the future.

Tree risk assessors collecting data.

CHAPTER 1

Step 1: Develop the Program of Work

Before implementing a tree risk assessment program, land managers should develop a plan to determine how to best allocate limited resources. The first step is to define the area where staff will perform tree risk assessments. After identifying the area(s), a manager must prioritize the sites and resources within it for survey and mitigation and select the appropriate survey type (Tier 1 Basic or Tier 2 Advanced). The program of work is completed within the scope of individual resource types (roads, developed recreation sites, or administrative sites) since the use patterns and frequency of surveys for these resources are intrinsically different—prioritize recreation sites with other recreation sites and roads with other roads. Coordinate with specialists (e.g., recreation, engineering, wildlife, aquatics, silviculture, timber, heritage, and fire) during this process as survey and mitigation options may have timing constraints, especially in project areas with federally listed species where consultation with regulatory agencies is required.

Developing the Program of Work for Tree Risk Assessments

- Assemble appropriate specialists
- Define area and/or sites for survey
- Prioritize areas/sites for survey
- Decide on survey type at each site
- Decide appropriate failure zone size for project area
- Decide if special considerations for dead trees are warranted
- Define the maximum acceptable risk rating for project areas or target types and the associated mitigation strategies

Prioritizing Survey Areas

Two factors drive the prioritization of surveys: the value of the infrastructure at the site and the amount of time people are exposed to potential tree hazards at that site. Local knowledge of site history and other management goals are also important, but in general:

- As infrastructure cost or value increases, so does the survey priority.
- As human exposure to risks increases, so does the survey priority.
  - Overnight use greatly increases exposure time
  - Operating season affects exposure to risks
- If knowledge of site history and forest type indicates an increased likelihood of tree failure at a site, survey priority increases.
- As use constraints increase, so does the survey priority (fig. 1.1).

In many instances agencies direct use patterns of the public (e.g., developed campgrounds with designated tent pads, backcountry sites where people are directed to camp within a certain distance of a post that designates a campsite, or signage and fencing that directs use to a specific area). In these cases, the survey priority would be higher than if use patterns were not being directed or "constrained."

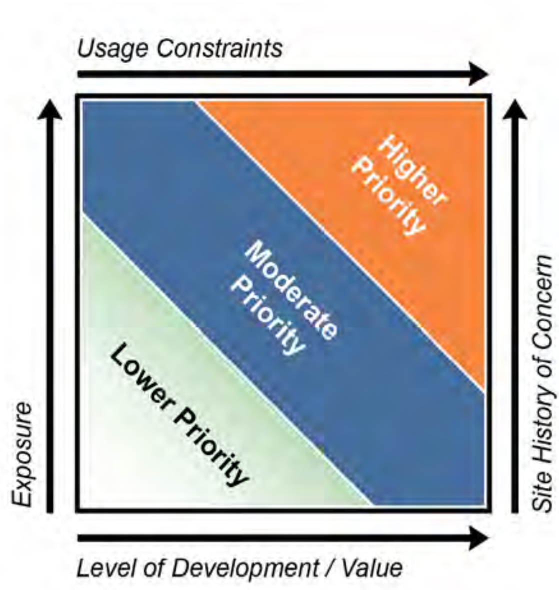


Figure 1.1—Considerations for prioritization of sites for tree risk assessments.

Local knowledge of a site's history and forest composition can influence survey prioritization. Priority will increase if a site has a history of tree failures, which may be related to past disturbances and the age and composition of the forest. There may also be other goals that overlap with tree risk assessments, such as silviculture activities in surrounding areas, fuels treatments, wildlife habitat improvements, etc. Ultimately, site prioritization is highly dependent on the knowledge, experience, and goals of the specialists developing the program of work. Prioritizing sites helps determine the most suitable survey type and the timing and frequency of tree risk assessments while aligning with available resources and acceptable risk levels. Consider developed sites, roadways, and worksites as separate groups and use criteria specific to each group during prioritization.

Developed Sites

Developed sites include administrative and recreation facilities. The level of development can vary widely—from a large campus of facilities that includes water and electric utilities to a campsite with a single signpost or marker. Survey prioritization depends on the type of infrastructure or development, the exposure time, the seasonality of operations, use patterns, site hazard tree history, and local unit objectives.

Sites With Overnight Occupancy

Campgrounds and other recreation and administrative sites designed for overnight occupancy (fig. 1.2) typically have the highest potential exposure and therefore are prioritized above other recreational and administrative sites.

Figure 1.2—A campsite designed for overnight recreational use.

Other Sites and Facilities

Generally, sites with higher levels of infrastructure, sites designed for extended occupancy, or sites with high occupancy rates should be prioritized over sites with lower development or occupancy or those designed for short-duration uses. Depending on resource availability and other site-specific or programmatic variables, not all developed sites may be surveyed every year. The prioritization discussion allows specialists and managers to develop a systematic approach and document the decision.

Prioritization hierarchy example for developed sites and facilities:

A. Administrative facilities, recreation sites with overnight occupancy, and snow parks where people are exposed in extreme weather
B. High-use trailheads, interpretive sites, and day-use areas
C. Moderate-use trailheads and day-use areas
D. Low-use interpretive sites and day-use areas
E. Low-use trailheads

Use (high, moderate, low) can be quantified for more explicit prioritization. Ensure ongoing vegetation conditions and stand health are considered in addition to the above hierarchy.

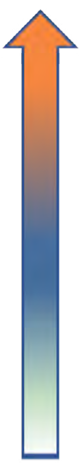
Roads

It is impracticable to conduct surveys and mitigate hazard trees on the thousands of miles of roads that travel through forests. Tree risk assessments and mitigation should prioritize areas with the highest risk. Areas and road segments with the highest volume of use, the greatest exposure times, and largest number of defective trees should have the highest priority. Forest Service roads may be prioritized by their **operational maintenance level (table 1.1).** Developed roads with higher traffic volume and speed of use (typically State routes or county arterial roads) may be given the highest priority for tree risk assessments, while roads that are restricted to high-clearance vehicles and have a low traffic volume may be lower in priority. Areas with increased tree mortality from disturbance events such as insect outbreaks, fires, or extreme weather should be given higher priority than areas with lower mortality or unchanged conditions. Other priorities may include roads of local concern or with unique circumstances, such as roads that provide access to rural communities or infrastructure (emergency egress routes, roads to power lines, access to fire lookouts and communication sites, etc.).

Table 1.1—Road maintenance levels used by the Forest Service

Maintenance level	Traffic type
1	In a period of storage, closed to highway-legal vehicles; open for nonmotorized uses; may be managed or designated as a motorized trail
2	Maintained for high-clearance vehicles; low traffic volume and low speed; may not be passable in periods of inclement weather; traffic consists of administrative, permitted, dispersed recreation, or other specialized uses
3	Open for standard passenger cars during normal season of use; low traffic volumes and speeds; local, commercial, and recreational use; aggregate surface
4	Moderate traffic volumes and speeds; typically two lanes of traffic and aggregate surface, but may be paved
5	High traffic volumes and speeds; generally paved; typically connect to county or State roads

Prioritization hierarchy example for roads:



A. Areas and road segments with constant exposure and where extensive damage to targets may occur, such as viewpoints, pullouts, or other places where people are encouraged to park their vehicle or any other place where vehicles or people are exposed to hazard trees for a long duration. Additionally, places where a work activity could occur for a long duration of time, such as a bridge replacement or other road reconstruction activity.

B. Short-duration exposure areas (e.g., intersections, stop signs, or emergency pull-outs).

C. Areas with intermittent but high-frequency exposure (e.g., high-traffic roads, timber haul routes, or areas with limited site distance (sharp corners).

D. Areas with low traffic volumes.

Ensure ongoing vegetation conditions and stand health are considered in addition to the above hierarchy.

Worksites

The type of work activity and the length of exposure determine when, where, and what type of tree risk assessments to conduct. Work activities present various levels of risk associated with the potential for inducing a tree failure. For instance, a worksite with heavy machinery presents a higher likelihood of influencing a hazardous tree to fail compared to one with only hand tools.

Work activities that involve direct tree contact, such as hand felling, vibration from earth-moving equipment, or rotor wash associated with helicopter operations, may warrant higher prioritization.

Survey Types and Frequency

Tree Risk Assessment Tiers

Two tiers of tree risk assessments, or surveys, can be performed—a simpler Tier 1 Basic survey or a more thorough and lengthier Tier 2 Advanced survey. The choice between them is dependent on factors that include visitor use, presence of targets, length of exposure, development type, current site conditions (including forest health and disturbance conditions), survey crew availability, and budgetary constraints (fig 1.3). The length of time between surveys and the survey type may change over time based on changing priorities and conditions. **Regardless of survey type, all trees within striking distance of targets—1 to 1.5 times the height of the tree—need to be assessed** (refer to chapter 2, "Determining Potential Failure Zone").

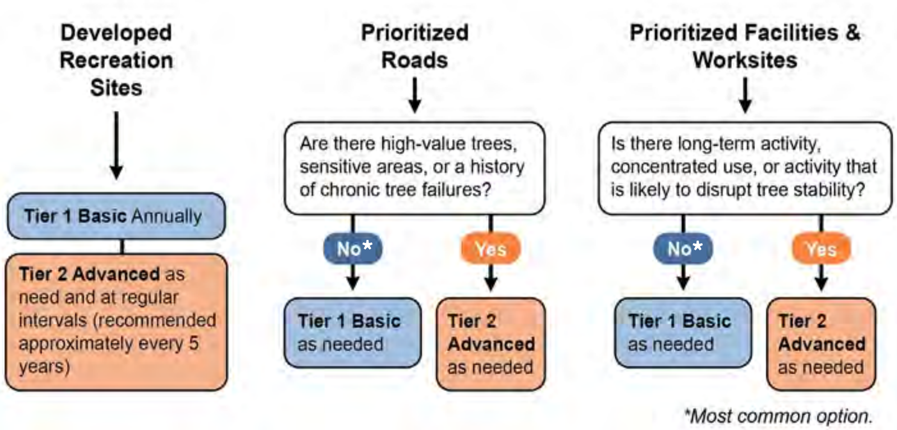


Figure 1.3—Suggested survey level and frequency based on resource and activity type.

Tier 1 Basic Survey

A Tier 1 survey is a visual assessment of a tree or population of trees for the purpose of identifying obvious defects. While a basic survey entails only a visual assessment of the tree, it requires a thorough and systematic examination of a tree on all sides from its base to its crown (described in chapter 4). The Tier 1 survey focuses on identifying trees with obvious defects that contribute to high or very high failure potential.

Trained individuals conduct this visual assessment on foot. A Tier 1 assessment can efficiently cover a large area and identify dead trees, hung-up or root-sprung trees, broken or hung-up tops and large branches, or trees with cracks, evident decay, or other obvious visible defects that may contribute to tree failure. Tier 1 surveys may be initiated from a slow-moving vehicle with good visibility to all possible hazard trees, so long as the person doing the survey is not operating the vehicle. A Tier 1 survey from a slow-moving vehicle can be a first step to evaluate what tree defects may be present. However, it does not constitute a complete survey and is not appropriate for roads that have parked cars, picnic areas, parking areas, long-term occupancy, or high year-round use.

A Tier 1 survey will help determine if a particular tree or a given site requires a more in-depth examination to properly identify the risk of tree failure (i.e., initiate a more advanced Tier 2 survey). For example: A Tier 1 survey in a developed site identified conks of an unknown fungus on several trees. The extent of decay present and failure potential could not be easily determined so further examination was warranted.

Tier 2 Advanced Survey

A Tier 2 survey begins with a thorough visual inspection that evaluates the butt, stem, and crown of the tree on all sides. Advanced surveys require in-depth knowledge of the structural properties of different tree species and identification of less obvious defects associated with potential tree failure, such as heartwood decay and root disease. When signs and symptoms indicate tree damage that presents a risk of failure, a more thorough examination is advisable to determine the extent to which the damage has compromised structural integrity.

Tier 2 surveys often include drilling trees when decay is suspected or excavating roots to assess for root disease. On a tree that requires additional investigation to determine its failure potential, assessors may use tools such as sounding mallets, increment borers or drills, binoculars, hand lenses, hatchets, and Pulaskis. Tier 2 surveys also involve inspecting the area in the immediate vicinity of each tree, looking for both obvious and subtle patterns of underlying forest health issues or site conditions that may lead to tree failure. Advanced surveys cannot be completed from a vehicle and always require a full inspection of all sides of a tree.

Determining Survey Type and Frequency

Surveying Developed Sites

For developed sites with overnight use, Tier 1 surveys should be conducted annually before seasonal opening and after the severe weather season(s) has passed. This frequently occurs in the spring as winter weather conditions often result in tree damage. Damage caused by winter storms or wind events brings attention to the most defective trees or limbs and may help to identify the portions of stands with root disease or stem decay. For developed sites without overnight use, Tier 1 survey frequency should be based on site occupancy, exposure, infrastructure, and resource availability. In the event of a changed condition, such as a flood or windthrow event, additional Tier 1 surveys may be justified between the normal inspection cycle.

In high-use developed recreation sites, such as campgrounds, Tier 2 surveys provide a more comprehensive assessment and may identify recurring forest health issues that require regular monitoring. Tier 2 surveys should be completed at regular intervals as deemed feasible and appropriate based on the management agency's standards (e.g., every 5 years) and after major disturbances such as fire, insect outbreaks, or on sites with chronic damage from root disease or stem decay. Between Tier 2 surveys, an annual Tier 1 survey should be adequate to capture changes from one year to the next.

Surveying Road Systems

Unlike developed recreation areas, surveys along road systems are generally not conducted at regular intervals. Tier 1 surveys will likely only occur on the highest priority road systems, and survey frequency will change based on recent disturbances, priorities, and funding. Outside of the highest priority sections of roads identified on a unit, road surveys are often triggered by large-scale disturbance events (see chapter 8 for additional considerations).

Tier 2 surveys may occur along forest roads under unique circumstances; however, these are typically limited in scope and frequency to areas with high-value trees, high use, or sensitive resources (e.g. critical habitat, areas with heritage trees).

Surveying Worksites

At worksites, a Tier 1 survey can be useful in determining the risk posed to field-going personnel. However, many temporary work sites with limited exposure and infrequent use, such as those associated with field surveys, tree planting, or short-term road maintenance projects (linear grading, brushing, culvert maintenance) (fig. 1.4) may not require an explicit Tier 1 survey. Personnel can use the information in this field guide to identify potential hazards at these temporary work sites.

A Tier 2 survey may be more appropriate on worksites where there is long-term activity, concentrated use, or the activity may disrupt a tree's stability (e.g., landings on logging units or road reconstruction activities, such as rock crushing operations and culvert or bridge replacement projects).

Figure 1.4—Dead trees surrounding a temporary worksite.

Determine Failure Zone Size, Considerations for Dead Trees, and Maximum Risk Rating

After identifying, prioritizing, and assigning survey types to areas for assessment, several additional decisions must be made. Selecting a standard for failure zone size, which will define the survey area, should be decided and documented prior to conducting surveys. It is best practice to remove dead trees in developed recreation sites; outside of developed recreation sites retention of dead trees may be considered where exposure is low. The maximum risk rating for different project areas will be different and based on the level of exposure and target value. That is, not all project areas have a maximum risk rating of 10; for example, some forest roads may only have a maximum rating of eight. Thus the maximum possible risk rating should be determined and then an appropriate maximum acceptable risk rating above which mitigation will occur should be established for each project area individually.

Field Supplies

Before heading to the field, identify and gather the necessary maps, survey records, forms, and equipment to conduct thorough tree risk assessments. Useful field equipment may include binoculars, sounding mallet, increment borer, battery-powered drill, detailed site maps, appropriate tree risk assessment forms or applications for mobile data collection, hand lens, Pulaski, hatchet, laser/clinometer, logger's tape, diameter tape, flagging, and appropriate field guides. A device with Global Positioning System (GPS) capabilities is helpful to record the location of trees.

CHAPTER 2

Step 2: Determining Potential Failure Zone

The potential that a tree or tree part may strike a target is determined by where the tree or its parts will likely land in the event of a failure (fig. 2.1), known as the potential failure zone. A tree with no target in the potential failure zone poses no risk and does not need a tree risk assessment.

Figure 2.1— Picnic table damaged by failure of a hazard tree.

The potential failure zone is the area that any part of a failed tree might reach. Variables for calculating the potential failure zone include the height of the tree or length of the defective tree part, the direction and degree of slope, and the direction and degree of tree lean. Decide and document the standards for potential failure zone area prior to conducting surveys, which will help define the survey area and provide a justification if a project or individual tree removal is challenged. Additionally, documentation of site conditions at a specific area or tree will provide justification for changes to that area's or tree's potential failure zone, if necessary. Recommendations included here do not supersede guidance provided by relevant regulatory agencies or agency policies.

When on slopes, tree failures typically result in the tree or its parts sliding or rolling distances well beyond what would normally be calculated for a failure zone on flat ground. In these situations, the rolling material may strike other trees, rocks, or debris on the ground and fling material a considerable distance. This is especially true when failures occur in stands of dead trees or on slopes devoid of vegetation.

Total Tree Failure

On level ground, the recommended potential failure zone is generally equal to the height of an individual tree, though that may increase to 1.5 times the height of the tree for certain situations, depending on local conditions and regulatory policies. Hence, the potential failure zone around the base of the tree is a circle defined by a radius that is 1 to 1.5 times the height of the tree (fig. 2.2). A 100-foot-tall tree's potential failure zone has a radius of 100–150 ft.

On sloped ground, the failure zone downhill of the tree should be extended to whatever distance is necessary to protect people or property if the tree slides or rolls (fig. 2.3). For targets uphill from the tree, the total tree height should be adequate to calculate failure zone.

Figure 2.2—Potential failure zone for a tree without a lean on a site without slope.

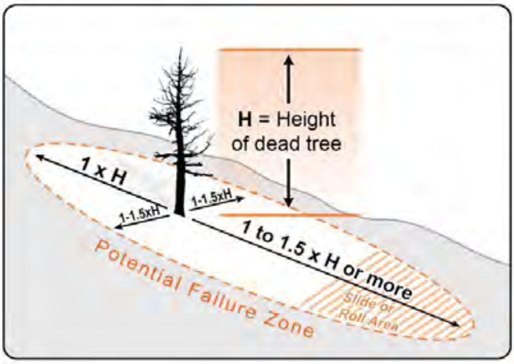


Figure 2.3—Potential failure zone for a tree without a lean on a site with a slope.

Leaning Trees

It is important to differentiate between slightly leaning trees and trees with significant leans (15 degrees or more). For trees leaning 15 degrees or more, the failure zone is an area—the same radius as the 1 to 1.5 times the height of the tree— beginning at the base of the tree and extending toward the direction of the lean and out 90 degrees on either side of the tree from the direction of the lean (fig. 2.4). The area behind the lean is not within the failure zone but allowance for backlash should be made. If the tree has other structural defects in addition to a significant lean, the direction of potential failure is unpredictable and a radius equal to 1 to 1.5 times the height of the tree should be used on all sides.

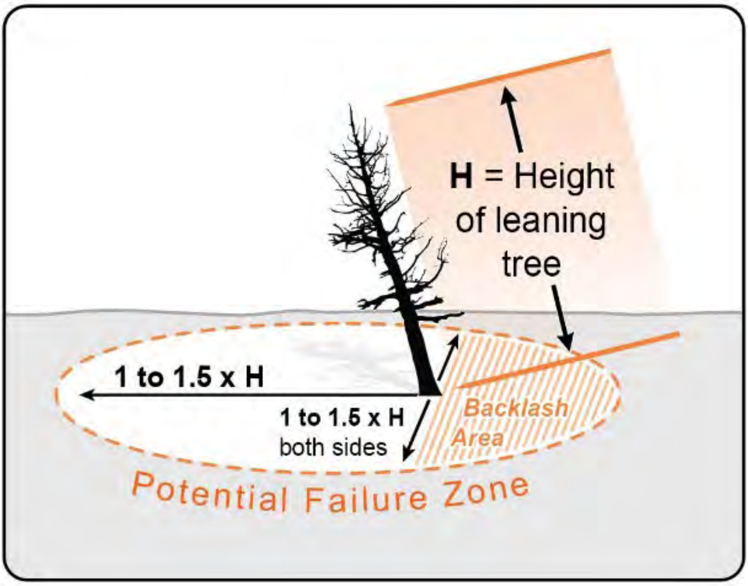


Figure 2.4—Potential failure zone for a tree with a lean 15 degrees or more.

Tree Part Failure

For tree parts, such as tops, forks, or branches, the recommended potential failure zone is 1.5 times the length of the tree part that would become dislodged, even on flat ground. Often treetops or parts dislodge when it is windy and can be carried farther than just the length of the tree part, as has been documented on fork failures in ponderosa pine in central Oregon (Oblinger 2016). On level or sloped ground where the tree has no discernable lean, determine the length of the part that could be dislodged; for forks or codominant stems, the section often includes some distance below where the forks could separate. The failure zone forms a circle around the tree with a radius equal to 1.5 times the length of the defective part (fig. 2.5). For instance, if a dead top is 10 ft long, the potential failure zone has a radius of 15 ft from the base of the tree. On sloped ground where the dislodged part may slide or roll downhill, the failure zone should be extended on the downhill side (fig. 2.6).

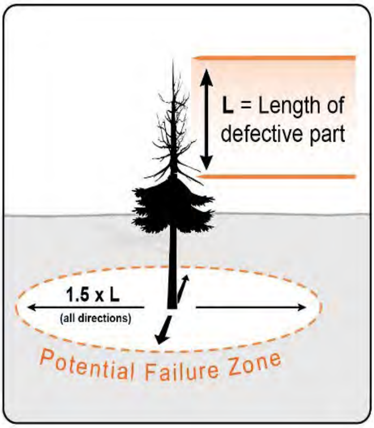


Figure 2.5—Potential failure zone on a site with no slope when only the top or a portion of the tree may fail.

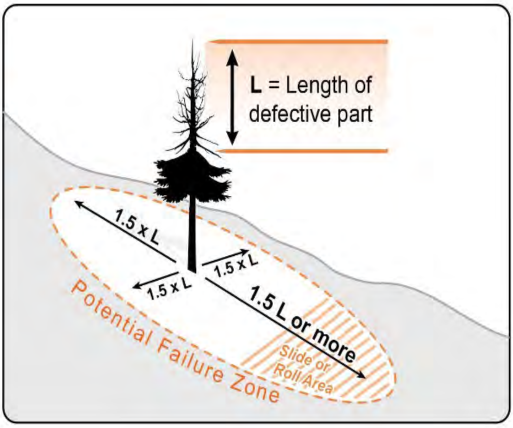


Figure 2.6—Potential failure zone on a site with slope when only the top or a portion of the tree may fail.

CHAPTER 3

Step 3: Determining Impact Potential Rating

Once a tree's potential failure zone has been determined, an assessment of the targets that exist within that area needs to be made and an impact potential rating assigned. **Impact potential incorporates the probability of occupancy (exposure) and extent of injury or damage to property (consequences) that may result if tree failure occurs.** The consequences of a tree failure are estimated by determining the maximum extent of loss if a target is struck. Exposure and the consequences of failure are expressed in relative terms and are used to determine the impact potential rating on a scale of 1 to 5 (tables 3.1 and 3.2).

On some occasions the size of the tree or its failed part may be considered in evaluating impact potential. For example, only larger trees may be considered for work activities where the operator of heavy machinery is in a protected cab that can withstand some impact from smaller trees. In other situations, such as tent camping or working without overhead protection, even smaller trees or their parts may cause serious injury or death.

Local knowledge of the site will help inform the impact potential rating. Variables to consider when determining the rating include:

- Use patterns of developed recreation sites
- Road use patterns (e.g., traffic speed and volume, use of pullouts, seasonal closures)
- Type of target and occupancy (e.g., designated tent sites, restrooms, overnight parking areas, picnic tables, information boards, scenic viewpoints)
- Work activity and duration (e.g., tree planting, trail construction, culvert replacement)
- Probable timing of tree failure (e.g., failures tend to be more common during storms and when soils are saturated)

A streamlined approach may be applied in a project area where impact potential remains constant, such as a right of way or a transmission line or corridor. In this situation all trees will have the same impact potential rating, which allows tree risk assessment and mitigation decisions to focus on the failure potential ratings.

Rating Impact Potential

Refer to tables 3.1 and 3.2 for examples.

- **Impact Potential = 1** (rare exposure or no damage)
  - Areas not commonly occupied
  - Damage to targets is unlikely to occur
- **Impact Potential = 2** (occasional exposure or minor damage)
  - Areas occupied infrequently
  - Damage to targets is rare (improbable but has occurred in the past) and consequences are likely to be negligible
- **Impact Potential = 3** (intermittent exposure or moderate damage)
  - Areas occupied intermittently, not continuously or steadily
  - Damage to targets is unlikely (remotely possible) and consequences will likely be tolerable
- **Impact Potential = 4** (frequent exposure or significant damage)
  - Areas occupied for a large portion of the day, week, or season
  - Damage to targets is possible but not probable and consequences will likely be substantial
- **Impact Potential = 5** (constant exposure, extreme conditions, or extensive damage):
  - Areas occupied at nearly all times or when weather conditions are extreme
  - Damage to targets is probable and consequences will likely be severe; or serious injury or death is likely

Table 3.1—Impact potential rating examples for developed recreation sites, infrastructure, and administrative facilities, including roads within these sites

Survey area	Impact potential rating				
	1	2	3	4	5
Developed recreation & infrastructure sites	Undeveloped or inaccessible area of site with incidental use	Garbage cans, small kiosks/signs, trails within sites, gates, fee tubes	Outbuildings, picnic tables, water systems, designated parking areas, amphitheaters, large information kiosks, fish cleaning stations, boat launches	Restrooms, mechanized fee machines, high-use undeveloped areas such as swimming beaches	Designated sites established for overnight use such as tent pads, overnight RV parking including snow parks, cabins, or yurts; ski lifts
Roads within developed recreation and administrative sites	None	Scored based on frequency of use and exposure. For roads outside of these areas use table 3.2.			Parking areas for snow parks
Administrative facilities	Areas around facilities that are undeveloped or with incidental use	Areas around facilities such as fences, garbage cans, gates, infrequently used parking areas	Areas of facilities that are infrequently used, such as outbuildings, warehouses, vehicle storage sheds, and training sites; regularly used parking areas	Areas around facilities that are intermittently used, associated utilities such as water and wastewater systems, parking areas where vehicles are stored or kept overnight	Areas around facilities that have regular occupancy, such as offices, work centers, lodges, visitor centers, and sleeping quarters

This table gives recommendations on how to assign impact potential ratings based on the features of a site and takes into consideration occupancy of sites and consequences should failure occur. These are suggestions only. Ratings may need to be adjusted to fit unique circumstances in the survey area.

Table 3.2—Impact potential rating examples for roads and worksites outside of developed recreation and administrative sites

Survey area	Impact potential rating				
	1	2	3	4	5
Roads	Roads placed in storage or administratively closed; nonmotorized traffic only and roads with areas of low traffic volumes	Roads with areas of moderate traffic volumes, such as timber haul routes	Sections of roads with short duration exposure, such as intersections, stop signs, turnouts, or limited sight distance areas	Sections of roads with high traffic volumes and long-duration exposure; high-use parking areas and viewpoints	Sections of roads with heavy traffic volumes resulting in congestion, bus stops, snow parks, or high-priority assets such as bridges
Worksites	Work activities that are conducted by foot traffic only, occur in remote sites, have limited use, or are visited infrequently, such as areas used for research	Work activities that are completed with hand tools, concentrated and at times stationary, and visited for consecutive periods of time, such as larger trail maintenance projects	Work activities that are transient and of short duration that require both foot traffic and heavy equipment use over a larger area, such as road maintenance projects	Work activities where heavy equipment use is concentrated, stationary, and the site is used for prolonged periods of time, such as a bridge replacement project	Work activities where direct tree disturbance is likely, such as logging operations, road decommissioning, or rotor wash from helicopter operations

This table gives recommendations on how to assign impact potential ratings based on the features of a site and takes into consideration occupancy of sites and consequences should failure occur. These are suggestions only. Ratings may need to be adjusted to fit unique circumstances in the survey area.

CHAPTER 4

Step 4: Evaluating Failure Potential

When the potential failure zone of a tree intersects a target and an impact potential is determined, it is then necessary to determine if the tree has any structural defects and, if so, assign a failure potential. The failure potential of a tree is the probability that a tree or its part will break or collapse. It is determined by examining a tree in its entirety to identify defects that could contribute to failure. Once defects are recognized, a score of 1–5 is assigned that estimates the likelihood that a failure could occur (very low, low, moderate, high, or very high potential for failure). If a tree has a target and a defect, then there is risk of injury or property damage, and the impact potential and failure potential should be used to calculate the overall risk rating for that tree.

Evaluating failure potential involves:

- determining tree species group,
- identifying tree defect(s),
- assigning failure potential of tree or tree part, and
- reevaluating failure zone if a defect is restricted to a part of a tree.

This chapter discusses the process for systematic tree examination, defines failure potential ratings, outlines important defects that may contribute to failure potential, gives guidance on how to assign failure potentials (tables 4.1 and 4.2), explains and discusses how to determine sound rind thickness (tables 4.3 and 4.4), and provides additional recommendations for mitigating dead trees (table 4.5).

Assigning a failure potential rating is usually the most difficult and time-consuming step in a tree risk assessment, as it involves careful evaluation of a tree for defects that may compromise the structural integrity of the tree and increase its likelihood for failure. Careful evaluation of a tree includes looking for external indicators of defects, which then can lead to an estimation of the extent of hidden, internal defects. In general, older trees are more likely than younger trees to have defects that have accumulated over time. In addition, thin-barked, nonresinous species such as true firs, hemlocks, alders, and poplars are more likely to have significant structural defects than thick-barked, resinous species such as pines, Douglas-firs, or larches.

Systematic Tree Examinations in Surveys

Regardless of which survey type is being conducted, it is essential to perform a systematic tree examination using a method that is organized, logical, and repeatable. All trees within striking distance of targets (1 to 1.5 times tree height) in the predetermined survey area should be included in the survey, and evaluations should follow a logical pattern through a site (e.g., starting at campsite 1 or entrance) and include known or established reference points (e.g., fire rings, permanently fixed picnic tables, mile markers).

Systematic tree examinations are used in both Tier 1 and Tier 2 surveys and often begin around the base of the tree, examining the condition of exposed roots and root collar, then proceed to the butt, bole, limbs, and top. Examine all sides of the tree. Evaluate trees from a distance to get a full view of the crown to compare the vigor and overall appearance of trees relative to their nearest neighbors. The view from a distance allows the assessor to detect leans, dead trees or tops, forks, large dead branches, or crown symptoms that may indicate root disease, such as thinning or fading crowns and stress cone crops. Evidence of a changed condition or widespread tree disease is often easier to detect from a distance.

Tier 1 surveys focus on obvious visible defects; reference table 4.1 for assigning a failure potential rating to the tree being surveyed. The failure potential defects in table 4.1 highlight the most obvious visible defects associated with tree failure.

Tier 2 surveys also focus on obvious visible defects included in Tier 1 surveys but require a more thorough inspection of trees and their associated defects as well as a more comprehensive understanding of the defects (appendix 1). Use table 4.2 to assign a failure potential rating to trees in an advanced survey.

Tier 2 surveys may require additional steps, such as drilling trees when decay is suspected or closely inspecting roots to check for root damage or disease. Tier 2 surveys pay particular attention to scanning for conks or mushrooms on and around trees since these can be indicators of internal decay, and assessors performing Tier 2 surveys should have additional training to identify different types of decay organisms and pathogens.

Assessors conducting Tier 2 surveys will also have more training on how to identify site-level indicators of chronic forest health issues (fig. 4.1). These indicators may be overlooked by the untrained eye and require careful evaluation. Their identification often leads to detection and correct diagnosis of problems in adjacent trees that otherwise appear healthy. Careful examination of the area near each tree is necessary to identify both obvious and subtle evidence of past or ongoing damage by pathogens, insects, or other factors. Examples include stumps, tree roots, and dying trees that may indicate root or butt rot pathogens. Broken-out tops, large branches lying on the ground, and windthrown or wind-shattered trees should be examined to determine contributing factors such as internal stem or root decay.

Figure 4.1—Forest pathologists training students to recognize tree defects.

Rating Failure Potential

Tables 4.1 and 4.2 cover common tree defects and their associated failure potential ratings for Tier 1 and Tier 2 surveys, respectively. These tables, along with sound rind thickness guidelines in tables 4.3 and 4.4, should be referenced when evaluating tree defects and determining failure potential ratings.

Failure potential is rated on a scale of 1 to 5 in order of increasing severity and likelihood of failure.

- **Very low failure potential = 1**
  - Live trees or tree parts without visible defects.
- **Low failure potential = 2**
  - Trees or tree parts with only minor defects.
- **Medium failure potential = 3**
  - Trees or tree parts with moderate defects.
- **High failure potential = 4**
  - Trees or tree parts that are highly defective.
- **Very high failure potential = 5**
  - Tree or tree part failure has started or is most likely to occur in the near future even without extreme conditions present.

Determining the failure potential of a tree includes answering the following questions about the presence of defects and an estimation of their severity:

- Is the tree alive or dead?
- Is the tree leaning (to what extent), root sprung, or hung up in another tree?
- Is the tree's root system exposed, undermined, or severed?
- Is there evidence of recent fire damage?
- Are there bole cracks?
- Is there a dead, broken, or detached limb or top 3 inches or more in diameter?
- Are two or more defects acting synergistically to cause an increased probability of failure?

In addition to the defects above, when doing a Tier 2 survey look for the following:

- Are there indicators of root diseases or butt decays?
- Are there bole wounds or visible evidence of decay?
- Are there other stem defects, such as fungal or mistletoe cankers?
- Are fungal conks present?
- Is the tree top forked or does it possess multiple tops or stems?

Defects Influencing Failure Potential

Brief descriptions of the main types of defects are provided below. Tables 4.1 and 4.2 provide failure potentials associated with each type and severity of defect. Additionally, appendix 1 presents detailed information on specific disease and defect identification. Even with a list of potential defects to look for, estimating the potential for tree failure can be difficult because many variables interact with existing defects, including tree size, age, form, species, condition, and location. For example, some sites may be more prone to extreme winds, which may lead to more frequent multiple or forked stem failures.

Dead Trees

As dead trees decay, sound wood and structural stability decrease. Dead trees with no other defects have a wide range of fall rates based on tree species, size, and site conditions. The decay process is generally slower for resinous species, such as Douglas-firs, pines, and larches, than nonresinous species because resin (i.e., pitch) inhibits fungal growth (refer to table A2.1 in appendix 2). Cedars also have a slow rate of decay due to decay-inhibiting compounds in their heartwood.

In general, dead trees decay from the outside in as sapwood decays rapidly following tree death. Tree failure potential increases proportionately with the number of years a tree has been dead as sapwood decay fungi readily infect and decay the roots, boles, and tops of dead trees. Smaller dead trees, tops, and branches with proportionately more sapwood decay faster than larger dead trees or tree parts which have proportionately more heartwood. Therefore, tree species and size are incorporated into tables 4.1, 4.2, and 4.5.

Multiple Defects With Synergistic Effects

Trees often display multiple structural defects. If one defect worsens another defect, they are considered **synergistic** (fig. 4.2). The potential for tree failure increases dramatically with the combined effects of multiple defects if they act synergistically. This often happens if the defects occur on the same location within a tree or if a tree is leaning and has damage at the base. For trees with multiple defects that are not synergistic, use the failure potential rating of the defect with the highest rating. Examples of multiple, synergistic defects that indicate increased failure potential include:

- Trees with a combination of heart rot, stem cankers, stem wounds, or sap rot
- Trees with a combination of structural bole cracks and wounds, butt rot, or heart rot
- Trees with forked tops with evidence of heart rot near fork
- Leaning trees with root disease or butt decay

- Leaning trees with structural cracks
- Leaning trees with undermined or severed root systems
- Leaning trees with bole or roots consumed by fire
- Dead trees with structural defects, such as heart rot or structural bole crack
- Dead trees with butt or root rot
- Dead trees with undermined roots, severed roots, or fire-consumed boles and roots

Figure 4.2—A western redcedar actively failing with multiple, synergistic defects (structural crack, significant lean, and undermined root system).

Leaning, Root-Sprung, or Hung-Up Trees

Trees with a significant lean (15 degrees or more) can result from root decay or damage, butt decay, or from high winds that cause root wrenching, often associated with saturated soils. Trees with recent leans (fig. 4.3) may be root sprung and have recently disturbed soil around the base (i.e., soil heaving). Root-sprung trees are highly susceptible to failure because the anchoring capacity of the roots is compromised by being partially pulled out of the ground (fig. 4.4). Often these trees are considered failures in progress (fig. 4.5).

Trees with older leans may have formed vertical tops since the lean developed (i.e., a corrected lean) and reaction wood to compensate for the lean, resulting in a lower potential for failure (fig. 4.6). All leaning and root-sprung trees should be examined for other defects that cause additional structural weakness, such as bole wounds (especially located at the base of the tree), bole cracks, and undermined root systems, as there is an increased likelihood of failure due to the synergistic interaction of defects. Additionally, any tree or tree part that is hung up in another tree has a very high failure potential.

Figure 4.3—Alders with significant, uncorrected leans above a playground where previous failures have occurred. Standing trees should be checked for root pulling.

Figure 4.4—A western hemlock with decayed roots and cracked soil, indicating a root-sprung tree.

Figure 4.5—An actively failing western hemlock with a significant lean, freshly disturbed soil, and root pulling.

Figure 4.6—A ponderosa pine with a corrected lean.

Exposed, Undermined, or Severed Root Systems

Exposed roots are often associated with soil compaction or erosion in heavily used areas, and wounds on exposed or severed roots can act as entry courts for decay fungi. Exposed roots reduce anchor points and load-bearing capacity for a tree. Undermined roots result from erosion, seasonally high water or flooding events, and excavation or construction activities (fig. 4.7). Cracked or broken roots and roots severed mechanically by construction, road building, and maintenance activities can result in failures (fig. 4.8). Failure potential is determined by the proportion of sound, structural roots remaining in the ground.

Figure 4.7—Undermined root systems along a riverbank.

Figure 4.8—White firs with severed and exposed roots in a construction site.

Recent Fire Damage

Fires can consume tree roots or boles and cause either instant or delayed tree mortality. Consumption of the bole or roots during fire increases structural instability. After fire, boles and roots should be carefully examined for changes to their structural integrity due to wood consumption. When decay is present before a fire, consumption during a fire can be extensive. For example, trees with preexisting fire scars often fail during new fire events or in the months after a fire, especially when additional wood is consumed. Trees with fire damage are rated for failure potential based on the amount of bole consumed (i.e., cross section of the bole missing) (fig. 4.9), the number of quadrants of structural roots consumed by fire (fig. 4.10), or both (tables 4.1 and 4.2).

Failure potentials for trees with recent fire damage (less than 5 years) are generally higher than trees with other bole wounds or internal decay, since fire can cause more immediate changes in structural stability compared to other decay agents. Over time, live trees with fire damage may remain standing and will slowly start to compensate by adding reaction wood, which will increase the tree's stability over time. Live trees with older (5 years or more) fire damage should be assessed using the "bole wounds" row in table 4.2.

Figure 4.9—Tree with fire damage and bole consumption.

Figure 4.10—Tree with fire damage and root consumption.

Bole Cracks

Cracks in the main stem usually tell an important story and reveal to the assessor that a closer inspection of the tree's interior is warranted. Cracks can be superficial or structural and can be caused by lightning (fig. 4.11), wind, or frost. Cracks can also occur when there is extensive internal decay resulting in the tree starting to fail. Frost cracks (fig. 4.12) are caused by extreme cold, are common at higher elevations and in cold-air drainages, are identified by nearly vertical callus lines of raised bark that extend from the ground up, and are not commonly associated with tree failures. Ring shake, caused by wind stress resulting in separations between annual tree rings, indicates partial failure when severe.

Figure 4.11—Tree with evidence of a previous lightning strike.

Figure 4.12—Tree with a sealed frost crack.

The failure potential of bole cracks is evaluated based on whether they extend deep into the wood, are open or sealed (i.e., the tree has formed callus tissue around or over a crack), are associated with visible internal decay, or there is evidence of independent movement (figs. 4.13 and 4.14). Cracks affecting critical wood structure, such as vertical cracks associated with internal decay or horizontal cracks across the wood grain, are considered structural cracks and are rated with higher failure potential than superficial or sealed cracks. Superficial cracks do not penetrate deep into the wood. An open crack with independent movement—where the sides slip past each other or the crack widens and compresses—indicates partial failure has already occurred or is in the process of occurring.

Figure 4.13—An actively failing Douglas-fir with an open structural crack and no evidence of decay.

Figure 4.14—Tree with an open structural crack and extensive heartwood decay.

Dead, Broken, or Detached Limbs or Tops

Examine large (3 inches or greater in diameter) dead tree tops and branches thoroughly. Dead tops and branches on live trees eventually break out and fall to the ground. Before dead tops and branches fail, they often rot in place and may be held by little or no sound wood. Large dead tops and branches should be examined for decay and instability indicated by conks, crumbling sapwood, cracks, woodpecker activity, or nesting cavities (fig. 4.15). Dead tops and branches with large, structural cracks indicate the highest potential to fail.

Trees should also be examined for large (3 inches or greater in diameter) detached branches. Free-hanging branches should be identified and removed as needed (fig. 4.16). Note that the potential failure zone for dead or broken tops and branches is 1.5 times the length of the defective part (not the whole tree height).

Root Diseases and Butt Decays

While fungi that cause root diseases and butt decay are primary contributors to tree failures, they can be a challenge to recognize, identify, and evaluate (fig. 4.17). If root disease symptoms (e.g., basal resinosis or crown thinning) or signs (e.g., fruiting bodies such as mushrooms or conks) are evident or suspected, the root collar, butt, and major lateral roots should be inspected for fruiting bodies, ectotrophic mycelium, mycelial fans under the bark, incipient decay (often visible as discoloration or stain of the wood), or advanced decay in the wood.

Figure 4.15—A Douglas-fir with dwarf mistletoe brooms and an old dead top with evidence of previous breakage and cavities from wildlife use.

Figure 4.16—A detached limb hung up in adjacent trees. Photo by Dave Shaw.

Figure 4.17—A root disease center in a campground. The pattern of old dead, new dead, and declining trees, as well as shrubs occupying the opening, indicates a root disease center where standing live trees should be checked for root disease signs and symptoms.

A Pulaski, or similar excavation tool, can be used to uncover roots (out to 1 yard, if needed) and to chop into them for further examination. At least two major roots should be examined for root disease if preliminary evidence suggests it is present. The roots closest to infected (i.e., hollow or decayed) stumps, windthrown trees, or obvious root disease centers should be examined first, since they are the ones most likely impacted. Large structural roots can be further inspected with an electric drill to determine if decay is present.

Identifying the specific root disease is crucial to accurately assess a tree's potential for failure (table 4.2), since disease effects (including spread) vary by type of disease and even the affected tree species. Often, the type of root disease in an area can be identified by observing site patterns, such as decay present in nearby dead trees, windthrown tree root systems, and stumps. Nearby stumps and roots should be examined for evidence of advanced decay or conks that may indicate and help identify root or butt rot pathogens. Once the root disease is identified, failure potential is rated by determining whether a tree is considered a susceptible species, has any symptoms, is within a certain distance of other infected trees, or is in an area where other trees have failed due to the disease (table 4.2). Refer to appendix 1 for more information on identifying individual fungi that cause root and butt decays, their hosts, and how the associated defect may contribute to tree failure.

Bole Wounds

Tree wounds are injuries that break the bark of the stem or branch. A wound is considered open if wood is exposed or a hollow interior is visible. Fresh wounds on living trees can become entry points for stem decay or canker-causing fungi (fig. 4.18). Wounds on nonresinous tree species, such as true firs and hemlocks, generally result in more internal decay than do wounds on resinous species. Wounds on Douglas-firs or pines are often covered with resin, which prevents the establishment of decay fungi (fig. 4.19).

Decay takes time to develop, sometimes decades. Old wounds should be carefully examined for evidence of decay (fig. 4.20). Failure potential due to decay behind bole wounds is evaluated by determining the amount of sound wood present at the wound. This is referred to as the sound rind, and its thickness, as a proportion to a tree's diameter inside the bark, determines the failure potential of the wounded tree (table 4.2). Refer to the "Sound Rind Thickness and Determining the Extent of Decay" section (pp. 57–62) for information on how to measure sound rind thickness and correlate sound rind with failure potential.

Figure 4.18—A fresh wound on a spruce, which may provide an entry court for decay fungi.

Figure 4.19—An old wound on a ponderosa pine; resin covered the wound and prevented the establishment of decay fungi.

Figure 4.20—An old basal wound on a grand fir with evidence of advanced decay.

Western Gall Rust, Mistletoe Cankers, or Other Fungal Cankers

Cankers are caused by many species of fungi that infect and kill portions of the boles and branches of conifers and hardwoods, or by parasitic plants called dwarf mistletoes. Cankers can cause topkill, branch death, or stem malformation (fig. 4.21). Stem breakage at malformations caused by western gall rust may occur, particularly on lodgepole pines, as distortion of cells reduces wood strength. Stem malformations can be infected and subsequently decayed by other fungi and the wood colonized by insects, thus increasing the likelihood of stem breakage.

Failure potentials of trees with western gall rust, mistletoe cankers, or other fungal cankers are rated based on the proportion of the cross section of the stem with malformed wood (refer to the relevant rows in the "Bole" section of table 4.2). If malformations appear to be associated with open wounds or decay, it may be necessary to determine the sound rind thickness (table 4.4) and use the "bole wound" row in table 4.2. Refer to appendix 1 for example photos.

Visible Evidence of Decay and Fungal Conks

In most cases, stem decays are detected by the presence of conks (fig. 4.22). A conk, or fruiting body, is a reproductive structure formed by many species of decay-causing fungi. Conks are external signs that some wood decay is likely taking place inside the tree. Conks generally develop at the site of old branch stubs or wounds. Absence of conks, however, does not necessarily indicate that a tree is free of internal decay. Other visible evidence of decay may include exposed decay, cracks, cavities, or evidence of carpenter ant or termite activity in the wood.

Figure 4.21—A stem canker caused by western gall rust.

Figure 4.22—A large Ganoderma conk on a western hemlock.

Heart rot is decay caused by fungi that are confined to the heartwood of living trees (fig. 4.23). Heartwood decay fungi are most damaging to mature trees, regardless of their size. The extent of defect is best correlated with tree age and not diameter. For conifer species, most of the damage associated with heart rot fungi occurs in trees that are more than 150 years old. Decay-prone species such as western hemlocks and true firs, however, may have substantial decay at younger ages. The type and severity of decay also varies by fungal species. Refer to appendix 1 for more information on identifying decay fungi and how they contribute to tree failure.

Figure 4.23—Advanced decay in the heartwood caused by *Echinodontium tinctorium.*

Once the fungus that is causing decay is identified, the failure potential of the tree can then be rated based on the number and size of conks on the tree. Refer to the "other heart rot conks" row in table 4.2 if the fungal species cannot be identified. If the stem near a conk can be easily drilled, the sound rind thickness can be used to determine failure potential (table 4.3). Decay and structural defects high in a tree can be assessed with binoculars. On rare occasions, high-value trees can be climbed and drilled.

If trees without external defects are suspected to have internal decay, they can be evaluated for the presence of heart rots by several methods, such as striking the tree trunk with a sounding mallet or the blunt end of a hatchet and listening for a dull or hollow sound. If heard, assessors can further quantify sound rind with a drill or increment borer.

Sapwood decay is caused by fungi that occur primarily in the sapwood and is most commonly found in dead trees (fig. 4.24). The fungi that cause sapwood decay compete poorly with other fungi that decay heartwood and are seldom found past the sapwood/heartwood interface. In living trees, sapwood decay fungi occur on woody tissue killed by other agents, most often bark beetles, mechanical wounds, or weather damage. On dead trees, especially those killed by bark beetles, sapwood decay can progress very rapidly.

Small-diameter stems and tree tops have a high proportion of sapwood to heartwood and can decay and fail shortly after tree death. Failure potential of a tree with sapwood decay is rated by the presence of conks, whether the tree is alive or dead, and sometimes by the percent of sound rind in table 4.3. See the "Recommendations for Dead Trees" section in this chapter for discussion on failure rates of trees based on size and amount of sapwood.

Figure 4.24—Decay in the sapwood of a tree.

Trees With Forks or Multiple Tops

Forked trees, or trees with codominant stems, are evaluated based on the shape of the fork, presence of embedded bark below the fork, and presence of additional failure defects. In general, U-shaped forks are less prone to breakage than V-shaped forks (figs. 4.25 and 4.26). Forks that are tightly V-shaped can split and break when radial growth at the point of branch convergence forces the acute angle further apart, eventually weakening the fork and increasing the likelihood of failure (fig. 4.27). Embedded, or included, bark is indicated by a seam between the forked stems and occurs when bark grows between the union of codominant or multiple stems. On forked trees where a top or codominant stem previously failed, remaining tops or stems are at risk of failing after the strength of the wood is compromised from splitting at the base of the fork. All tree forks should be regularly examined because additional indicators of structural instability, such as open cracks, decay, fresh pitching, or conks, often suggest weakening and predisposition to failure.

Figure 4.25—A U-shaped fork.

Figure 4.26—A tight V-shaped fork on a western hemlock with codominant stems.

Figure 4.27—A bigleaf maple with a V-shaped fork that is failing as evidenced by the open crack below the fork.

Rating Tree Defects for Tier 1 Basic Surveys

In a Tier 1 survey, a visual inspection is performed for obvious defects, such as but not limited to dead trees, large dead or detached tops and branches, undermined root systems, open structural cracks, leaning or root-sprung trees, fire damage, or when multiple defects interact synergistically to indicate very high failure potential. Tier 1 surveys will reference table 4.1 and focus on the most visibly defective trees and tree parts—those with high and very high failure potential. A Tier 1 survey may include recommendations on the need for a Tier 2 survey in developed sites, triggered by an abundance of defective or dead trees by unknown causes, symptomatic trees needing additional diagnoses, the presence of many wounded trees that may need to be assessed for internal decay, the presence of individual high-value trees, or if a larger forest health issue is suspected.

Table 4.1—Tier 1 basic survey failure potential (FP) ratings based on defects

Defects	FP 1 (very low)	FP 2 (low)	FP 3 (medium)	FP 4 (high)	FP 5 (very high)
Dead trees	None	None	None	**These species ≥30” DBH with no preexisting defect:*** cedar, Douglas-fir, juniper, western larch, western white pine	All other species/sizes of dead trees
Synergistic defects**	None	Two or more FP 1 defects **with** synergistic effects	FP 2 defect combined with FP 2 or FP 1 defect **with** synergistic effects	FP 3 defect combined with FP 3 or FP 2 defect **with** synergistic effects	FP 4 defect combined with FP 4, FP 3, or FP 2 defect **with** synergistic effects
Broken or uprooted trees supported by other trees	None	None	None	None	All species/sizes
Leaning or root-sprung trees	All leans <15 degrees **without** freshly disturbed soil	Corrected leans ≥15 degrees **without** freshly disturbed soil	Uncorrected leans ≥15 degrees **without** freshly disturbed soil	Uncorrected leans ≥15 degrees **with** evidence of root or butt damage **and without** freshly disturbed soil or root pulling	All leans **with** freshly disturbed soil or root pulling
Undermined or severed roots	>75% of structural roots remaining in ground	>50–75% of structural roots remaining in ground	25–50% of structural roots remaining in ground	<25% of structural roots remaining in ground	Only with synergistic defects
Live, recent (<5 years) fire-damaged trees This row can apply to other damages affecting the cross section of stem	Scorched bark with no bole consumption **and** no fire-consumed structural roots	<25% of bole cross-section fire-consumed or missing **and** no fire-consumed structural roots	25–50% of bole cross-section fire-consumed or missing **or** one quadrant of fire-consumed structural roots	>50–75% of bole cross-section fire-consumed or missing **or** two quadrants of fire-consumed structural roots	>75% of bole cross-section fire-consumed or missing **or** >two quadrants of fire-consumed structural roots

Table 4.1 —Tier 1 basic survey failure potential (FP) ratings based on defects (continued)

Defects	FP 1 (very low)	FP 2 (low)	FP 3 (medium)	FP 4 (high)	FP 5 (very high)
Bole cracks	None	Sealed cracks without evidence of decay	Open structural cracks, not extending deep into wood and without evidence of decay	Open or sealed structural cracks with evidence of decay	Open structural cracks with evidence of active failure (e.g., splitting)
Detached tops or branches (>3" diameter) FP refers only to detached parts, not the whole tree	None	None	None	None	All detached parts
Dead tops or branches (>3" diameter) FP refers only to tops or branches, not the whole tree	Cedars or western larch Pine tops killed slowly by rust fungi with resin impregnation	Douglas-fir or pines **without** evidence of decay	Hemlocks, spruces, true firs, or hardwoods **without** evidence of decay	Any dead top or branch **with** indicators of decay such as cavities, conks, or exposed decay	Any dead top **with** open cracks or a lean (evidence of active failure) or any dead branch **with** open cracks

*Preexisting defects associated with dead trees include, but are not limited to, broken tops, broken large branches, undermined root systems, open structural cracks, large wounds, cavity openings, or leans. The presence or site history of root diseases affecting similar tree species should also be considered when examining other defects associated with dead trees.

** Synergistic defects are those that amplify or exacerbate each other (see pp. 39–40 for description).

DBH = diameter at breast height

Rating Tree Defects for Tier 2 Advanced Surveys

In a Tier 2 survey, inspections are more comprehensive and thorough and focus on more than the obvious defects found in a Tier 1 survey. Tier 2 surveys also evaluate additional, less obvious structural defects that may contribute to failure. In many cases this requires knowledge of tree species, the ability to identify the causal agents, and determining the extent of internal decay. Table 4.2 details how to rate failure potentials based on defects; for several defects, it is necessary to determine the sound rind thickness. This process is discussed below, and calculations are provided in tables 4.3 and 4.4.

Sound Rind Thickness and Determining the Extent of Decay

There are procedures and tools that tree risk assessors can use to estimate the amount of internal tree decay during Tier 2 surveys. If a tree has visible, external evidence of internal decay in the butt or bole (e.g., conks near tree base or at drilling height, wounds, or new cracks) or if the tree sounds hollow or dull when tapped with a mallet or back of a hatchet (i.e., sounded), the extent of the decay should be estimated to assess structural stability and assign the appropriate failure potential to the tree. This is done by calculating the sound rind thickness of the tree at the point of the defect.

Sound rind thickness is a proportional measurement of the solid, supporting, nondecayed (i.e., sound) wood compared to the extent of degraded or decayed wood present in a tree. Knowing the proportion of sound rind to the diameter of the tree inside the bark (known as diameter inside bark or “DIB”) at a defect helps determine a tree’s failure potential. Failure potential increases as the proportion of sound rind decreases in a tree.

In the absence of synergistic defects, conifers can lose up to 70 percent of the total cross-sectional area to wood decay (which is equivalent to about one-third of its strength or resistance to failure) without significantly increasing the level of hazard. This is equivalent to having a sound rind of 15 percent of the diameter inside bark (table 4.3, Wagener 1963). Table 4.3 displays sound rind thickness (in inches) for a range of stem diameters (estimated diameter inside bark) that equate to >25 percent, 15–25 percent, and <15 percent of sound rind and are associated with low, medium, and high failure potential ratings, respectively.

These guidelines are only appropriate for trees with internal decay and no additional defects (e.g., open wounds, synergistic defects). Trees with open wounds have a greater failure potential than nonwounded trees with equivalent sound rinds. Minimum sound rind thickness should be increased by at least

Figure 4.28—Using an increment borer to determine sound rind thickness on a tree with a *Phaeolus schweinitzii* conk.

25 percent in trees with open wounds. Table 4.4 shows the larger sound rind needed for trees with open wounds and should be used when determining failure potential for trees with open wounds.

Measuring Sound Rind

Estimate sound rind thickness at the height on the bole where the defect is most severe or in proximity to fungal conks (fig. 4.28). If the suspected defect is well above the ground, very valuable trees can be climbed and drilled; otherwise, defects high in a tree may be assessed with binoculars rather than by climbing, but sound rind cannot be determined. The percent of sound rind is based on the diameter inside bark (DIB) at the defect or point of drilling.

Coring with an increment borer is the preferred method to evaluate decay in soft-wooded species (e.g., cedar, spruce, cottonwood, aspen, or alder). Detecting decay is done by feeling for hollows and examining the wood chips, and it is much more difficult to feel subtle differences in decay in soft-wooded species when done with a battery-powered drill. Tree species that display buttressing or fluted butts (e.g., western hemlock and western redcedar) may require more sampling since the distal portions of fluted areas are often thicker.

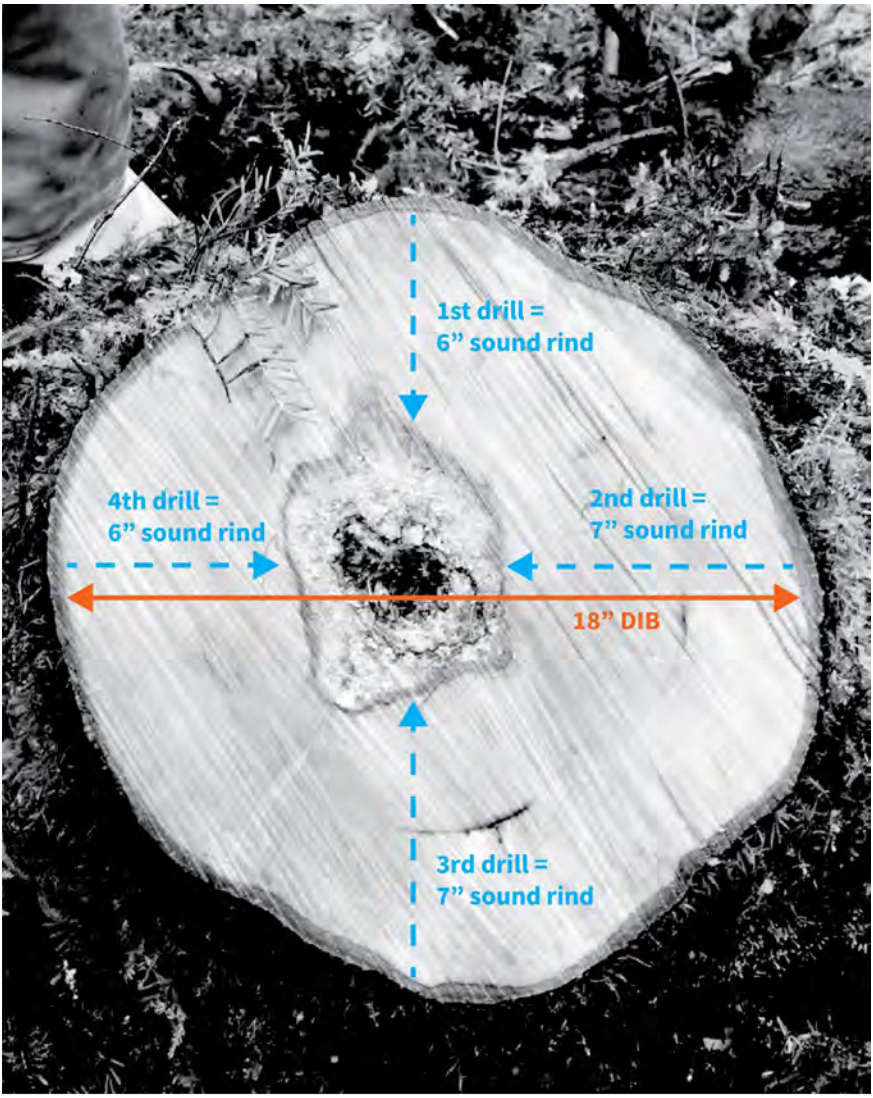
The DIB is estimated by measuring the diameter of the tree at the height of the defect and subtracting the bark thickness. The bark is not included in the tree diameter since it does not add structural integrity. Fire-resistant tree species, such as mature ponderosa pines and Douglas-firs, have thicker bark compared to thin-barked species, such as true firs, hemlocks, and cedars. Larger trees also tend to have thicker bark. An increment borer can be used to measure bark thickness on a few sample trees to help with estimations.

Once DIB is determined, drill three or four times (extending into the center of the tree) around the circumference of the bole to estimate the extent of the decay (fig. 4.29). For very large trees, the center of the tree may be inaccessible and drilling depth may be limited to drill bit or increment borer length. In this case, use table 4.3 or 4.4 to determine the drilling depth necessary to assign various failure potentials. If a wound or bole crack is present, drill perpendicular to the face of the wound or crack on both sides and directly opposite the defect (fig. 4.30).

The depth of sound rind for each measurement should be recorded and the average of the measurements calculated (see fig. 4.29). For example, if your drill reached internal decay after 6 inches into the wood of a tree bole, your recording of sound rind is 6 inches for that drill site. If subsequent drillings reached decay at 6, 7, and 7 inches, then the average sound rind thickness would be 6.5 inches ([6+6+7+7]/4 = 6.5). **The average should not include rind thickness at an open wound, which would be 0 inches.**

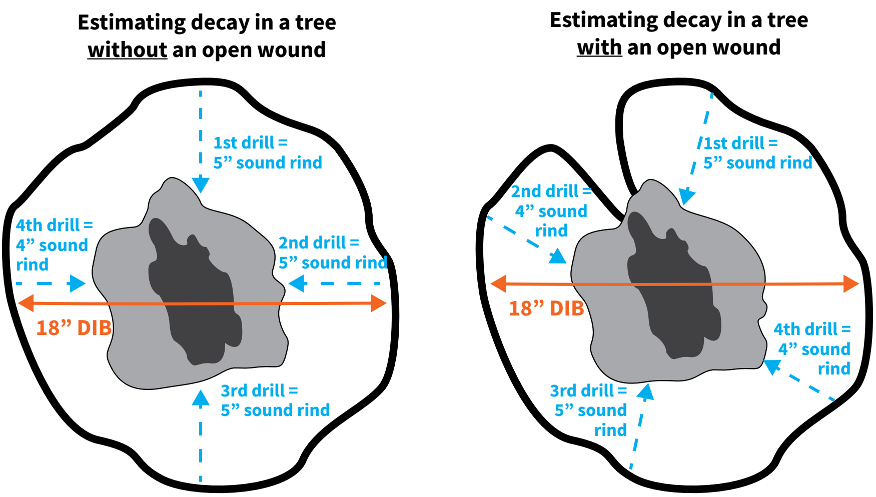
Overview: Measuring Sound Rind and Assigning Failure Potential

1. Measure tree diameter at height of the defect and estimate diameter inside bark (DIB)
   a. Determine whether the tree has an open wound in proximity to the defect
2. Use a drill or increment borer to estimate sound rind thickness
   a. Drill three to four quadrants around the bole and average the depth of the sound wood (in inches)
   b. Each drill depth should only extend the radius of the bole (to the center)
   c. Drill at the height of the defect
3. **Option 1:** Use the average sound rind and DIB to rate failure potential using table 4.3 (trees without open wounds) or 4.4 (trees with open wounds)
4. **Option 2**: Calculate percent sound rind and use a specific defect indicator row in table 4.2 to assign failure potential
   a. Percent sound rind is equal to average sound rind divided by tree DIB
   b. Use percent sound rind to determine if failure potential is low, medium, or high for a specific defect in table 4.2 (e.g., bole wounds or butt rot)



Average sound rind (ASR) = Total depth of all drills / Number of drills
Percent sound rind = ASR/DIB
ASR = (6”+7”+7”+6”)/4 drills = 6.5”
Percent sound rind =
6.5/18 = 36%

Figure 4.29—Example of sound rind thickness measurements in a cross section of a tree without an open wound with 18-in diameter inside bark (DIB) and some internal decay. Note how decay transitions from early/incipient decay (lighter color) to advanced decay (darker color, very little wood left).



Average sound rind (ASR) = Total depth of all drills / Number of drills
Percent sound rind = ASR/DIB

ASR = (5"+5"+5"+4")/4 drills = 4.75"
Percent sound rind =
ASR/DIB = 4.75/18 = 26%

ASR = (5"+4"+5"+4")/4 = 4.5"
Percent sound rind =
4.5/18 = 25%

Figure 4.30—Examples of estimating sound rind thickness in cross section of two trees: one without an open wound (left, use table 4.3 to determine failure potential) and one with an open wound (right, use table 4.4 to determine failure potential). Gray areas indicate decay (darker is advanced decay and lighter is incipient decay).

Trees may fail with more than the minimum sound rind thickness when synergistic defects are present. Extra caution should be taken when evaluating trees with multiple defects (e.g., trees with basal wounds and a significant lean, trees with butt decay and a significant lean, forked trees with a heart rot conk directly below the fork); **sound rind thickness guidelines should be used with caution since they were developed for trees with a single defect.** Assessors should assume trees with multiple, synergistic defects are more unstable and use the sound rind thickness as one factor in determining a tree's structural instability.

When monitoring trees with heart rot or butt rot, assessors should visually evaluate changes in the tree on an agreed upon frequency, looking for new cracks, wounds, leans, root pulling, or other defects associated with internal decay. Once sound rind is determined, trees should be drilled as appropriate to minimize drill wounds (as decay advances slowly in most tree species), unless other changes are noted. The frequency of drilling depends on the initial sound rind thickness, the type of decay, tree species, and the vigor of the tree.

The rate of radial growth affects future sound rind thickness. If growth is rapid, strength loss from advancing decay will be partially offset or perhaps even negated by the added strength of new wood. This is because decay is often compartmentalized within a column that is the size of the tree when it was first wounded; new wood formed after wounding usually does not decay unless the tree is wounded again. Callus formation around a wound indicates the tree is attempting to seal the wound and is an indicator of tree health and vigor.

Sound rind thickness guidelines apply to the bole only and not to the roots or root collar. Although the presence of bole wounds can be compensated for as explained above, other visible and hidden defects associated with the decay column should be considered in the assessment (refer to the “synergistic defects” row in table 4.2).

Table 4.2—Tier 2 advanced survey failure potential (FP) ratings based on defects

	Defect	FP 1 (very low)	FP 2 (low)	FP 3 (medium)	FP 4 (high)	FP 5 (very high)
Dead trees	**Dead trees**	None	None	None	**These species ≥30” DBH with no preexisting defect:*** cedar, Douglas-fir, juniper, western larch, western white pine	All other species/ sizes of dead trees
Whole tree	**Synergistic defects****	None	Two or more FP 1 defects **with** synergistic effects	FP 2 defect combined with FP 2 or FP 1 defect **with** synergistic effects	FP 3 defect combined with FP 3 or FP 2 defect **with** synergistic effects	FP 4 defect combined with FP 4, FP 3, or FP 2 defect **with** synergistic effects
	Broken or uprooted trees supported by other trees	None	None	None	None	All species/sizes
	Leaning or root-sprung trees	All leans <15 degrees **without** freshly disturbed soil	Corrected leans ≥15 degrees **without** freshly disturbed soil	Uncorrected leans ≥15 degrees **without** freshly disturbed soil	Uncorrected leans ≥15 degrees **with** evidence of root or butt damage **and without** freshly disturbed soil or root pulling	All leans **with** freshly disturbed soil or root pulling
Root diseases and root defects	**Dead conifers in root disease centers**	None	None	None	Cedars	All trees except cedars

Table 4.2—Tier 2 advanced survey failure potential (FP) ratings based on defects (continued)

	Defect	FP 1 (very low)	FP 2 (low)	FP 3 (medium)	FP 4 (high)	FP 5 (very high)
Root diseases and root defects	**Live trees in laminated root rot centers** caused by *Coniferiporia sulphurascens* (p. 125) Check for butt rot in nonsymptomatic trees Signs and symptoms include ectotrophic mycelium, laminated decay with setal hyphae, foliage thinning or yellowing, basal resinosis, and stress cones	Hardwoods and cedars	Pines or Sitka spruce **without** signs or symptoms	Douglas-fir, mountain hemlock, or true firs **without** signs or symptoms **and** >25’ from known infection source Engelmann spruce, western hemlock, or western larch **without** signs or symptoms	Douglas-fir, mountain hemlock, or true firs **without** signs or symptoms **and** <25’ from known infection source Any species **with** signs or symptoms	Any species **with** signs or symptoms **and** in areas with evidence of windthrown trees with the same root disease
	Live trees in Armillaria or Heterobasidion root disease centers caused by *Armillaria* spp. (p. 117) or *Heterobasidion* spp. (p. 122) Check for butt rot in nonsymptomatic trees Signs and symptoms include mycelial fans, basal resinosis, foliage thinning or yellowing, stress cones, and conks or mushrooms of pathogens	Tolerant species without signs or symptoms	Susceptible species **without** signs or symptoms **and not adjacent** (>50’) to windthrown trees with same root disease	Susceptible species **without** signs or symptoms **and adjacent** (<50’) to windthrown trees with the same root disease	Any species **with** signs or symptoms **and not adjacent** (>50’) to windthrown trees with same root disease	Any species **with** signs or symptoms **and adjacent** (<50’) to windthrown trees with same root disease

Table 4.2—Tier 2 advanced survey failure potential (FP) ratings based on defects (continued)

	Defect	FP 1 (very low)	FP 2 (low)	FP 3 (medium)	FP 4 (high)	FP 5 (very high)
Root diseases and root defects	**Live trees in black stain or Port-Orford-cedar root disease centers** caused by *Leptographium* spp. (p. 120) or *Phytophthora lateralis* (p. 129)	Any species **with** or **without** signs or symptoms	None	None	None	None
	Undermined or severed roots	>75% of structural roots remaining in the ground	>50–75% of structural roots remaining in the ground	25–50% of structural roots remaining in the ground	<25% of structural roots remaining in the ground	Only with synergistic defects
Butt	**Butt rot** caused by *Phaeolus schweinitzii*, *Heterobasidion* spp., *Onnia* spp., *Ganoderma* spp., etc. (pp. 117–135) Use table 4.3 or 4.4 to determine failure potential with sound rind estimate	None	No decay of structural roots **or** sound rind >25% on trees without open wounds **or** sound rind >30% on trees with open wounds	Decay in <50% of structural roots **or** sound rind 15–25% on trees without open wounds **or** sound rind 20–30% on trees with open wounds	Decay in >50% of structural roots **or** sound rind <15% on trees without open wounds **or** sound rind <20% on trees with open wounds	Only with synergistic defects
	Live, recent (<5 years) fire-damaged trees	Scorched bark with no bole consumption **and** no fire-consumed structural roots	<25% of bole cross-section fire-consumed or missing **and** no fire-consumed structural roots	25–50% of bole cross-section fire-consumed or missing **or** one quadrant of fire-consumed structural roots	>50–75% of bole cross-section fire-consumed or missing **or** two quadrants of fire-consumed structural roots	>75% of bole cross-section fire-consumed or missing **or** >two quadrants of fire-consumed structural roots

Table 4.2—Tier 2 advanced survey failure potential (FP) ratings based on defects (continued)

	Defect	FP 1 (very low)	FP 2 (low)	FP 3 (medium)	FP 4 (high)	FP 5 (very high)
Bole	**Bole wounds** Use table 4.4 to determine failure potential with sound rind estimate	Superficial bole wounds (e.g., recently wounded Douglas-fir with pitch) with no decay associated	Sound rind thickness is >30% of stem diameter	Sound rind thickness is 20–30% of stem diameter	Sound rind thickness is <20% of stem diameter	Only with synergistic defects
	Bole cracks	None	Sealed cracks without evidence of decay	Open structural cracks, not extending deep into wood and without evidence of decay	Open or sealed structural cracks with evidence of decay	Open structural cracks with evidence of active failure (e.g., splitting)
	Mistletoe cankers (p. 167) **or fungal cankers** (p. 162) If decayed wood is observed use “bole wounds” row	<25% of cross section with deformed wood	25–50% of cross section with deformed wood	>50–75% of cross section with deformed wood	>75% of cross section with deformed wood	Only with synergistic defects
	Western gall rust from *Endocronartium harknessii* (p. 171)	<25% of cross section with deformed wood	25–50% of cross section with deformed wood	>50–75% of cross section with deformed wood	>75% of cross section with deformed wood	Only with synergistic defect
	Burls	Burls present	None	None	None	None
Conks	**Any conk where drilling is feasible:** use this row and sound rind thickness guidelines (table 4.3 or 4.4)**;** refer to the rows below for conks where drilling is not possible	None	Sound rind at conk >25% on trees **without** open wounds **or** sound rind at conk >30% on trees **with** open wounds	Sound rind at conk 15–25% on trees **without** open wounds **or** sound rind at conk 20–30% on trees **with** open wounds	Sound rind at conk <15% on trees **without** open wounds **or** sound rind at conk <20% on trees **with** open wounds	Only with synergistic defect

Table 4.2—Tier 2 advanced survey failure potential (FP) ratings based on defects (continued)

	Defect	FP 1 (very low)	FP 2 (low)	FP 3 (medium)	FP 4 (high)	FP 5 (very high)
Conks	**Quinine conks** of *Laricifomes officinalis* (p. 146)	None	None	None	One or more conk(s)	One or more conk(s) **and** indicators of significant decay (cavities, exposed rot, open structural crack)
	Rust-red stringy rot (Indian paint fungus) conks of *Echinodontium tinctorium* (p. 156) Large = ≥8” wide Small = <8” wide	None	Single small conk	Either a single large conk or multiple small conks **without** additional indicators of significant decay (cavities, exposed rot, open structural crack)	Multiple large conks **without** additional indicators of significant decay (cavities, exposed rot, open structural crack)	Any size or number of conks **with** indicators of significant decay (cavities, exposed rot, open structural crack)
	Red ring rot (white speck, pini) conks of *Porodaedalea pini* (p. 153) West of Cascades: large conks are ≥8” East of Cascades: large conks are ≥6”	None	Cedars, Douglas-firs, pines, or western larches with 3 or more large conks **not within** a 3’ long stem cylinder **or** 2 or fewer conks **within** a 3’ long stem cylinder **or** any number or location of small conks	Hemlocks, spruces, true firs, or hardwoods with 1 or more conk(s) of any size **without** evidence of extensive advanced decay or evidence of past failures associated with *P. pini* conks **or** cedars, Douglas-firs, pines, or western larches with 3 or more large conks **within** a 3’ long stem cylinder	Any species with 1 or more conk(s) of any size **with** evidence of extensive advanced decay or evidence of past failures associated with *P. pini* conks	Only with synergistic defect

Table 4.2—Tier 2 advanced survey failure potential (FP) ratings based on defects (continued)

	Defect	FP 1 (very low)	FP 2 (low)	FP 3 (medium)	FP 4 (high)	FP 5 (very high)
Conks	**Other heart rot conks** from *Fomitopsis* spp., *Laetiporus conifericola*, etc. (pp. 142–143)	None	One or more conk(s) **without** evidence of extensive decay on **decay-resistant species** (see table A2.1 in appendix 2)	One or more conk(s) **without** evidence of extensive decay on **decay-prone species** (see table A2.1 in appendix 2)	One or more conk(s) **with** evidence of extensive decay	Only with synergistic defect
	Sap rot conks from *Cryptoporus volvatus*, *Trichaptum abietinum*, *etc.* (pp. 160–162)	None	**Live, decay-resistant trees with conk(s)**; check for heartwood decay and use sound rind thickness guidelines to determine FP	**Live, decay-prone trees with conk(s);** check for heartwood decay and use sound rind thickness guidelines to determine FP	Dead trees with sap rot conks; use "Dead trees" defect row	Dead trees with sap rot conks; use "Dead trees" defect row
Tops and branches	**Forked tops and codominant stems and trunks**	None	U-shaped or V-shaped forks **without** embedded bark **and** no open cracks, decay, or conks	V-shaped forks **with** embedded bark **and** no open cracks, decay, or conks	All forks **with** open cracks, decay, or conks	All forks **with** open cracks **and** evidence of active failure (e.g., splitting, past breakage)
	Detached tops or branches (>3" diameter) FP refers only to detached parts, not the whole tree	None	None	None	None	All detached parts
	Dead tops or branches (>3" diameter) FP refers only to tops or branches, not the whole tree	Cedars or western larch **or** Pine tops killed slowly by rust fungi with resin impregnation	Douglas-fir or pines **without** evidence of decay	Hemlocks, spruces, true firs, or hardwoods **without** evidence of decay	Any dead top or branch **with** indicators of decay such as cavities, conks, or exposed decay	Any dead top **with** open cracks or a lean (evidence of active failure) or any dead branch **with** open cracks

Table 4.2—Tier 2 advanced survey failure potential (FP) ratings based on defects (continued)

	Defect	FP 1 (very low)	FP 2 (low)	FP 3 (medium)	FP 4 (high)	FP 5 (very high)
Tops and branches	**Black cottonwood branches** FP refers only to the branch, not the whole tree	Young trees with small branches; no decay or breakage in the crown	Large (>3" diameter), live branches **without** evidence of past breakage or decay	Large (>3" diameter), live branches **with** evidence of past breakage but **no** decay	Large (>3" diameter) live or dead branches **with** evidence of past breakage and decay	Large (>3" diameter) live or dead branches **with** open cracks
	Dwarf mistletoe brooms (p. 167) FP refers only to the broom, not the whole tree	Douglas-fir with large, live brooms (>10' diameter) **or** other tree species with live brooms	Any species with small, dead brooms	Any species with large (>10' diameter), dead brooms	Any species with any size live or dead brooms attached by a branch with open crack	Only with synergistic defect

*Preexisting defects associated with dead trees include, but are not limited to, broken tops, broken large branches, undermined root systems, open structural cracks, large wounds, cavity openings, or leans. The presence or site history of root diseases affecting similar tree species should also be considered when examining other defects associated with dead trees.

**Multiple defects with synergistic effects are those that amplify or exacerbate each other (see pp. 39–40 for description.)

Highlighted rows are also listed in the tier 1 basic survey (table 4.1).

DBH = diameter at breast height

Table 4.3—Thresholds for failure potential (FP) ratings based on diameter inside bark (DIB) and average sound rind for trees without open wounds

Tree DIB (in)	FP 2 (low) Sound rind thickness threshold (in) >25% DIB	FP 3 (medium) Sound rind thickness threshold (in) 15–25% DIB	FP 4 (high) Sound rind thickness threshold (in) <15% DIB
4	>1.0	0.6–1.0	<0.6
6	>1.5	0.9–1.5	<0.9
8	>2.0	1.2–2.0	<1.2
10	>2.5	1.5–2.5	<1.5
12	>3.0	1.8–3.0	<1.8
14	>3.5	2.1–3.5	<2.1
16	>4.0	2.4–4.0	<2.4
18	>4.5	2.7–4.5	<2.7
20	>5.0	3.0–5.0	<3.0
22	>5.5	3.3–5.5	<3.3
24	>6.0	3.6–6.0	<3.6
26	>6.5	3.9–6.5	<3.9
28	>7.0	4.2–7.0	<4.2
30	>7.5	4.5–7.5	<4.5
32	>8.0	4.8–8.0	<4.8
34	>8.5	5.1–8.5	<5.1
36	>9.0	5.4–9.0	<5.4
38	>9.5	5.7–9.5	<5.7
40	>10.0	6.0–10.0	<6.0
42	>10.5	6.3–10.5	<6.3
44	>11.0	6.6–11.0	<6.6
46	>11.5	6.9–11.5	<6.9
48	>12.0	7.2–12.0	<7.2
50	>12.5	7.5–12.5	<7.5
52	>13.0	7.8–13.0	<7.8
54	>13.5	8.1–13.5	<8.1
56	>14.0	8.4–14.0	<8.4
58	>14.5	8.7–14.5	<8.7
60	>15.0	9.0–15.0	<9.0
62	>15.5	9.3–15.5	<9.3
64	>16.0	9.6–16.0	<9.6
66	>16.5	9.9–16.5	<9.9
68	>17.0	10.2–17.0	<10.2
70	>17.5	10.5–17.5	<10.5
72	>18.0	10.8–18.0	<10.8
74	>18.5	11.1–18.5	<11.1
76	>19.0	11.4–19.0	<11.4
78	>19.5	11.7–19.5	<11.7
80	>20.0	12.0–20.0	<12.0
82	>20.5	12.3–20.5	<12.3

Diameter inside bark is measured at the defect. Look for synergistic failure defects to determine if a tree within these sound rind thickness guidelines should be given a higher failure potential rating. Modified from Wagener (1963) by expanding the range of diameters covered.

Table 4.4—Thresholds for failure potential (FP) ratings based on diameter inside bark (DIB) and average sound rind for trees with open wounds

Tree DIB (in)	FP 2 (low) Sound rind thickness threshold (in) >30% DIB	FP 3 (medium) Sound rind thickness threshold (in) 20–30% DIB	FP 4 (high) Sound rind thickness threshold (in) <20% DIB
4	>1.2	0.8–1.2	<0.8
6	>1.8	1.2–1.8	<1.2
8	>2.4	1.6–2.4	<1.6
10	>3.0	2.0–3.0	<2.0
12	>3.6	2.4–3.6	<2.4
14	>4.2	2.8–4.2	<2.8
16	>4.8	3.2–4.8	<3.2
18	>5.4	3.6–5.4	<3.6
20	>6.0	4.0–6.0	<4.0
22	>6.6	4.4–6.6	<4.4
24	>7.2	4.8–7.2	<4.8
26	>7.8	5.2–7.8	<5.2
28	>8.4	5.6–8.4	<5.6
30	>9.0	6.0–9.0	<6.0
32	>9.6	6.4–9.6	<6.4
34	>10.2	6.8–10.2	<6.8
36	>10.8	7.2–10.8	<7.2
38	>11.4	7.6–11.4	<7.6
40	>12.0	8.0–12.0	<8.0
42	>12.6	8.4–12.6	<8.4
44	>13.2	8.8–13.2	<8.8
46	>13.8	9.2–13.8	<9.2
48	>14.4	9.6–14.4	<9.6
50	>15.0	10.0–15.0	<10.0
52	>15.6	10.4–15.6	<10.4
54	>16.2	10.8–16.2	<10.8
56	>16.8	11.2–16.8	<11.2
58	>17.4	11.6–17.4	<11.6
60	>18.0	12.0–18.0	<12.0
62	>18.6	12.4–18.6	<12.4
64	>19.2	12.8–19.2	<12.8
66	>19.8	13.2–19.8	<13.2
68	>20.4	13.6–20.4	<13.6
70	>21.0	14.0–21.0	<14.0
72	>21.6	14.4–21.6	<14.4
74	>22.2	14.8–22.2	<14.8
76	>22.8	15.2–22.8	<15.2
78	>23.4	15.6–23.4	<15.6
80	>24.0	16.0–24.0	<16.0
82	>24.6	16.4–24.6	<16.4

Diameter inside bark is measured at the defect. Look for synergistic failure defects to determine if a tree within these sound rind thickness guidelines should be given a higher failure potential rating. Developed from Harvey and Hessburg (1992).

Recommendations for Dead Trees

Dead trees provide important ecosystem services, including wildlife habitat (fig. 4.31) and structural diversity; however, dead trees often have high failure rates and represent current or future hazards. The time from tree death to tree failure depends on variables such as a tree's size, age, species, and preexisting structural damage, as well as site conditions. Small dead trees generally decay more rapidly than large dead trees. Large trees typically break down with portions of the tops and branches failing first due to higher sapwood to heartwood ratios and the impacts of decay fungi and wood borers on sapwood. Cedar, western larch, western white pine, juniper, and Douglas-fir trees with a diameter at breast height 30 inches or greater, **with no preexisting defects,** may persist on the landscape for decades**.**

Tables 4.1 and 4.2 offer a simplified rating for dead tree assessments. This guide used the failure rates from DecAID (Mellen-McLean et al. 2017) to develop the failure potential ratings in table 4.5 by tree species and size and when the tree died. Table 4.5 can be used when a more nuanced approach to managing dead trees is desired (e.g., for a large-scale vegetation management plan, along roads with different levels of use patterns, after large-scale disturbances with different exposures). In table 4.5, recently killed trees are differentiated from old dead trees. Recently killed trees (i.e., trees that died less than 5 years ago) may still retain their dead needles, generally have most of their fine branches still attached, and have intact bark. Older dead trees (i.e., trees that died 5 or more years ago) typically are missing fine branches, have missing bark or no bark, branches have started failing, and tops may have broken out.

All dead trees should be examined for additional, preexisting defects that increase the risk of failure, such as bole cracks, evidence of heartwood decay, a lean, or root damage. Evidence of visible defects may be present prior to the tree's death or may occur as parts of a dead tree break out or "chunk down" in pieces.

More detailed snag fall rates that help guide failure potential determinations are available from DecAID, which can be used in project planning when there is a desire to retain more dead trees on the landscape. Tables 4.1, 4.2, and 4.5 all use a 30" diameter at breast height (DBH) threshold between failure potentials based on snag fall rate data from DecAID. During project planning, considerations for dead tree management and failure potential thresholds should take into account the recommended tree diameters that may be utilized by wildlife. These recommendations inform dead tree management decisions for individual land managers.

In developed sites—It is a best practice to remove dead trees the year they die or move potential targets outside the failure zone. Consider acceptable risk levels, especially in developed recreation areas and areas intended for overnight occupancy, if retaining dead trees, particularly given that branch and top failures of dead trees can occur long before total tree failure. A plan to mitigate dead trees in a timely manner should be implemented, ideally within a year or before the next season of use.

If dead trees are retained, they should only be retained in remote areas of developed sites with limited exposure. If older dead trees are present because they were overlooked in previous inspections or the area had not been surveyed previously (fig. 4.32), a more immediate response to mitigate the tree or close the site may be warranted (refer to chapter 5 for mitigation options). Where annual surveys are conducted, trees may die and needles turn red during the operating season in between inspection periods. In these cases, it is practical to delay mitigation until the end of the operating season as long as root diseases or decay are not evident on the recently dead or nearby trees.

On roads and worksites—If exposure is limited and of short duration, working around or driving by dead trees may pose little risk. Examples include work activities such as tree planting or stand exams that have limited exposure times in any one location and low-use roads where both target values and exposure time are limited. If exposure is of longer duration, such as road construction, culvert replacement, or along high-use roads, the risks may be too high to consider leaving any dead trees.

Considerations for dead tree removal projects include the scale of the project, density and number of dead trees (refer to chapter 8 for examples of large-scale mortality events), the time since tree death, the efficacy of mitigating all dead trees in one entry period to reduce repeated entries over time, and available resources (fig. 4.33). **Delaying dead tree mitigation involves inherent risks, including increased risks to faller safety.**

Figure 4.31—A woodpecker using a decaying snag. Courtesy photo by Alan Dyke.

Table 4.5—Alternative failure potential ratings for dead trees

Defect	FP 1 (very low)	FP 2 (low)	FP 3 (medium)	FP 4 (high)	FP 5 (very high)
Old dead (≥5 years) No foliage or fine branches present; bark is absent or falling off	None	None	None	**These species ≥30" DBH with no preexisting defects:*** cedar, Douglas-fir, juniper, western larch, and western white pine	**All other dead trees**
Recent dead (<5 years) All or some foliage and fine branches present; bark mostly intact	None	**These species ≥30" DBH with no preexisting defects:** cedar, Douglas-fir, juniper, western larch, and western white pine	**These species 10.0–29.9" DBH with no preexisting defects:** cedar, Douglas-fir, juniper, western larch, and western white pine	**All species ≥10" DBH with no preexisting defects except these species:** cedar, Douglas-fir, juniper, western larch, and western white pine	**All species <10" DBH AND all sizes of:** alder, aspen, and cottonwood

*Preexisting defects associated with dead trees include, but are not limited to, broken tops, broken large branches, undermined root systems, open structural cracks, large wounds, cavity openings, or leans. The presence or site history of root diseases affecting similar tree species should also be considered when examining other defects associated with dead trees.

DBH = diameter at breast height

Figure 4.32—An old dead tree in a developed recreation site.

Figure 4.33—A recreation area with older and ongoing tree mortality after a wildfire.

CHAPTER 5

Step 5: Determining the Risk Rating and Mitigation Options

Risk Rating

A tree's risk rating is calculated by adding its impact potential and failure potential. The assigned risk rating represents the overall risk associated with an individual tree based on its potential to fail and to cause damage (fig. 5.1). The range of possible risk ratings will differ depending on the extent of tree defects and the range of exposure and potential consequences (i.e., available impact potentials) should tree failure occur.

Failure potential of tree

Impact potential of target

IP/FP	1	2	3	4	5
1	2	3	4	5	6
2	3	4	5	6	7
3	4	5	6	7	8
4	5	6	7	8	9
5	6	7	8	9	10

Figure 5.1—Calculate the total risk rating by adding a tree's impact potential (IP) and failure potential (FP).

Applying Risk Ratings To Determine Mitigation Priorities

Once individual trees have been assigned a risk rating, the ratings can then be compared to the previously set maximum acceptable risk rating. The maximum acceptable risk rating defines which trees will be mitigated within a project area. For example, if maximum acceptable risk rating is set at 8 within a project area, all trees with risk ratings of 9 and 10 will be mitigated. There is little need for prioritization of risk mitigation work when the project area is small or involves few trees. However, in some cases there may be sites requiring more mitigation than available resources can handle or there is a need to accommodate work restrictions, so the workload may need to be prioritized.

Figure 5.2 provides suggested mitigation priorities by risk rating. The maximum acceptable risk rating chosen for mitigation will be determined by the deciding official, typically as part of the planning process (chapter 1). Thresholds for mitigating or monitoring trees will depend on visitation, development type, risk tolerance, availability of resources, and other site-specific and programmatic variables.

Risk rating	Mitigation priority
10	Extremely high
9	Very high
8	High
7	Moderate
5–6	Low-moderate
2–4	Low

Figure 5.2—Maximum risk ratings (and associated mitigation decisions) are relative to the maximum impact potential in a survey area. The survey area in this example has a maximum impact potential of 5 and therefore a risk rating range of 2–10.

Figures 5.1 and 5.2 show all possible risk ratings (2–10); however, at a given site or project area the maximum risk rating may be lower than 10 and is largely driven by the maximum impact potential.

For example:

- Areas in a campground or administrative site that have overnight occupancy may have a maximum impact potential of 5 and thus a maximum risk rating of 10. Trees with a risk rating of 10 represent the highest priority for mitigation in this project area, and the maximum acceptable risk rating may be set at 8.
- High-use trailheads or day-use sites may have a maximum impact potential of 4 and thus a maximum risk rating of 9. Trees with a risk rating of 9 represent the highest priority for mitigation in this project area, and the maximum acceptable risk rating may be set at 7.
- Along some road sections, the maximum impact potential may be 3, and even the most defective trees will have a maximum risk rating of 8. Trees with a risk rating of 8 represent the highest priority for mitigation in this project area, and the maximum acceptable risk rating may be set at 7.

Regardless of final risk rating, mitigation priority will be based on the maximum risk rating possible in a survey area.

Maximum acceptable risk rating above which mitigation will occur should be established for each project area individually. Thresholds can also be set at different levels within one project area or within a developed site. For example, one loop of a campground is open for year-round use while the rest of the campground is closed seasonally. The maximum acceptable risk rating in the section of the campground open year-round may be lower (e.g., 8) than the portion of the campground that is only open seasonally (e.g., 9).

Guidelines for Tree Risk Mitigation (adapted from ISA)

- Extremely high-risk trees—Mitigation should occur as soon as possible. Immediate action may be required to restrict access or move targets from the potential failure zone.
- Very high-risk trees—Mitigation should occur as soon as practical.
- High- and moderate-risk trees—Mitigation may not be required, but if necessary could occur when budget or work schedule allows. If the risk is acceptable to the manager, trees and targets could be retained and monitored.
- Low-moderate risk trees should be retained and monitored (if recommended), or mitigation may be considered depending on project.
- Low-risk trees—Should be retained and reinspected at the next inspection cycle.

Mitigation Options for Tree Risk Reduction

Once a risk rating is assigned, mitigation options can be determined for individual trees over the maximum acceptable risk ratings. These mitigations can focus on the tree, the target, or both the tree and the target.

Manage the Target

Mitigation options that manage the target, such as closing sites (fig 5.3), moving targets, or changing the use period or type, can reduce risk without the need to remove the tree or its parts. When site or area closures are so large that physical barriers or other closure methods are not practicable (e.g., large areas with tree mortality), posting warnings of the risk of tree failure at the site (e.g., along a trail or road system) or posting information on websites, user permits, or other publicly available resources can notify the public of potential hazards. These warnings are least effective in mitigating risk but may be considered in areas with limited use, exposure, and infrastructure, or if other mitigation actions are not possible or cannot be implemented within a reasonable timeframe.

Figure 5.3—Managing the target: Signage can notify users of hazardous trees or area closures.

Manage the Tree

In addition to removing the entire tree (fig. 5.4), pruning of defective branches or dwarf mistletoe brooms can help reduce risk without necessitating complete tree removal. Reducing the height of dead trees may also reduce the size of the potential failure zone to the point where high-value targets are no longer at risk. Topping live trees is not recommended due to the creation of large wounds that are entry courts for decay fungi, weaken a tree's natural defenses, and also may increase the likelihood of damaging insect attacks. Professional arborists employ other mitigation options such as cabling or bracing for extremely high-value trees, although this is rarely done in forested settings.

Figure 5.4—Managing the tree: A trained worker removing a hazard tree.

Monitoring

When the risk rating is below the maximum acceptable risk rating and a tree does not require immediate mitigation, monitoring is critical to determining when conditions have degraded to a point that mitigation becomes necessary. For sites visited regularly, such as high-use developed recreation sites, every tree within striking distance of a potential target should be assessed annually. Trees not requiring immediate mitigation but having structural defects (i.e., monitored trees) should be documented in such a way that allows an assessor to relocate the tree and defect to ensure ongoing monitoring occurs. If a tree requires monitoring, the assessor should look for changed conditions, such as increased lean, the development of new cracks, new use patterns, or newly constructed infrastructure, which could impact the original risk rating of the tree. **For sites that will be assessed only once or rarely, such as along remote road systems or worksites, monitoring may not be feasible, and the maximum acceptable risk rating may need to be adjusted to reflect the survey frequency.**

Wildlife and Heritage Considerations

When a particular hazard tree has significant scenic, wildlife, or cultural value—or if such a value is in question—it's best to consult with appropriate forest resource specialists to accurately determine the resource value before any mitigation action is taken. In some situations, moving a target or closing the site may be the preferred option for mitigation.

Dead trees or live, defective trees often provide valuable habitat for wildlife species (fig. 5.5). If such trees are hazards and require mitigation, compliance with laws and policies for protected species is required. This would include but is not limited to the Endangered Species Act, the National Forest Management Act, and individual national forest land and resource management plans (e.g., the Northwest Forest Plan).

Figure 5.5—An owl nesting in a madrone.

Actions that may affect federally listed, threatened, or endangered species or designated critical habitat require consultation with either the U.S. Fish and Wildlife Service (most fish, wildlife, plants) or the National Marine Fisheries Service (anadromous fish). Actions that affect proposed species or proposed critical habitat should be conferenced on with those agencies, especially with respect to the long-term implications for site management if the proposed listing is approved. Appropriate agency wildlife biologists, fish biologists, and botanists should be a part of the assessment and resolution to complete the necessary consultation or conferencing and reporting to the U.S. Fish and Wildlife Service or National Marine Fisheries Service when mitigation activities intersect with sensitive species habitat. In addition, the appropriate timing of mitigation measures, such as during seasonal restrictions, needs to be considered.

Local biologists and botanists can advise on the application of programmatic consultations to the project. In some cases, programmatic consultation has been conducted, which would negate the need for consultation on an individual project. Programmatic consultations often have specific mitigations that need to be employed to remain consistent with the concurrence or opinion and reporting requirements for implementation (e.g., number and size of trees felled and timing of mitigation).

Culturally modified trees (heritage trees) are important archeological sites and should be protected. A tree with any human-caused marking or object over 50 years old is a culturally modified tree (fig. 5.6). Examples of culturally modified trees include peeled cedar trees, trail blazes on trees, bearing trees, arborglyphs, and trees with old insulators or wires. If a culturally modified tree is identified as a hazard, it needs to be considered for mitigation, whether that is removing the target, topping the tree, or removing the hazard tree.

Contact a local agency archeologist before treating a heritage tree because other mitigation options may be available and additional documentation, like recording spatial coordinates and taking photos, may be required. Safety is always the priority, but it is important to notify a resource specialist if mitigation is recommended. Consultation with State historic preservation offices (SHPO) and Tribal councils may be required.

Other Considerations

Tree removals open the forest canopy and expose remaining trees to new wind patterns. This can increase the risk of windthrown trees, and this heightened vulnerability to windthrow can persist for several years following tree removals. In some cases, it is wise to keep sites closed until trees have had time to reestablish wind firmness.

When felling large, live Douglas-fir trees that will be left on site or when Douglas-fir dwarf mistletoe brooms are being pruned, a local entomologist should be consulted to ensure practices prevent future Douglas-fir beetle activity in the stand. When removing ponderosa pines, true firs, or hemlocks in areas not currently infested with Heterobasidion root disease, consult with a local pathologist to evaluate the utility of treating the newly created large stumps with an EPA-registered borate compound to reduce the potential for *Heterobasidion* species colonization of stumps and subsequent spread of Heterobasidion root disease.

Figure 5.6—A culturally modified ponderosa pine.

CHAPTER 6

Step 6: Documentation

Record keeping is critical to implement a successful hazard tree program and can be accomplished through a computer database, paper files, or mobile data collection application with appropriate workflows. Creating a hazard tree database is important for maintaining records through time and personnel changes. Documenting tree risk assessments will help to inform where, when, and at what frequency surveys should occur in the future. Associated data may also be useful in developing vegetation management plans (chapter 7) and can provide necessary information for decision making under National Environmental Policy Act (NEPA) or other laws requiring consideration and disclosure of environmental effects. Most importantly, information from surveys may serve as the official record of performance in the event of tree failure or litigation.

A record that an inspection occurred at the **site level** provides evidence that a survey was completed and is an important element of an effective tree risk program. Assessors should record the type of survey completed (Tier 1 Basic or Tier 2 Advanced), the date(s) of the survey, the overall area surveyed, and which trees were inspected within that area—such as "all trees within failure zone of targets (failure zone defined as 1.5 times the height of the individual tree or length of a defective part of a tree)" or "all trees with a failure zone (defined as the height of the individual tree or 1.5 times the length of the defective tree part) that includes the amphitheater" or "all trees with a failure zone that encompasses the road between mile markers 130 and 132 (failure zone is one tree height from the road edge)."

At the **tree level**, documentation provides evidence that a tree was examined and records the decision to mitigate or monitor a hazard tree. For any tree inspected, record its approximate location, species, a description of defects increasing the likelihood tree failure, its targets, the risk rating, recommended mitigation options, and other details as needed. For trees that will be monitored as their determined mitigation outcome, record additional details on the defect and its location, such as conk sizes and locations, estimated angle between forks, etc. In situations where mitigation of a known hazard tree is not pursued, proper documentation becomes increasingly important. Document mitigation actions, including type and date, when they occur.

Land management agencies may have field data forms they created and recommend for use to ensure data collection is consistent and meets agency standards (fig. 6.1). Mobile data collection platforms are available to record spatially explicit information on a tree's location (or locations of other features) in addition to the above information. A variety of mobile applications are available to collect survey information. Geographic information systems (GIS) staff can provide more information on mobile data collection for tree risk assessments and maintaining records in a hazard tree database.

Time and economic constraints often make it impractical or impossible to collect and record detailed data for every tree in every area surveyed. For this reason, it may be necessary to forego detailed documentation of inspected trees that have lower risk ratings. When this occurs, include a statement in the assessment form indicating that all trees in the survey area with a target that are not specifically listed were inspected and deemed low risk.

Uniform Tree Defects

Often after bark beetle outbreaks, wildfire, or drought there are many trees killed or presenting similar defects. In these situations, documentation may only entail tallying the number of dead trees to be mitigated by species and size classes or tallying those with similar defects. For example, in a campground of lodgepole pines killed by mountain pine beetles, the number of dead trees in each loop can be tallied and then the mitigation action recorded. A similar example can be applied to a road system (e.g., "242 lodgepole pines between 8- and 12-inches diameter killed by a recent high-severity fire treated between mile marker 10 and 11"). As always, communication with local specialists (wildlife, heritage, etc.) on required documentation for consultation or other purposes is crucial and may guide how to best tally trees.

Deviating From Established Variables

In some circumstances local knowledge of use patterns or the history of tree failures might lead managers to deviate from the recommendations outlined in this guide for failure zones, impact potentials, or mitigation thresholds. This can include removing trees with lower risk ratings or retaining trees with higher risk ratings. When this occurs, managers should document their rationale. For example, the failure zone may be increased when it is known that top failures often land beyond 1.5 times the length of the part due to recurring high winds. The impact potential may be increased if known use patterns show regular overnight occupancy when the site is not designed or designated for overnight use. Mitigating trees at lower risk ratings than the established maximum acceptable risk may occur when knowledge of site conditions and history suggests that failures occur at these lower levels. It is crucial to record these deviations and the logic behind them.

Figure 6.1—An example tree risk assessment form for developed recreation sites with suggested data elements.

Tier 1 ☐ Tier 2 ☐						Site Name:	Qualified Person:					Date:
For individual ☐ or groups of trees ☐				Maximum Impact Potential for Survey:			Maximum Risk Rating for Survey:					
Map/ Site#	Tree #	Tree Species (if known)	DBH	DIB	Sound Rind	Tree Condition, Defect or Disease	Impact Potential (1 - 5)	Failure Potential (1 - 5)	Risk Rating	Recommended Action	Comments	Action Taken (Date)
Notes:												

CHAPTER 7

Vegetation Management Plans

Developed sites and roads are often managed by removing hazard trees annually or periodically without planning for future desired conditions. Continual removal of hazardous trees without clear, long-term objectives for vegetation composition and structure at a site can lead to unintended consequences, such as undesirable tree species, lack of canopy cover, or lack of screening between campsites. Vegetation management plans should be established for developed sites to reduce the risk of future hazards, proactively manage forest health, and maintain desirable site conditions for visitors. An effective vegetation management plan will consider forest disturbance agents that influence forest health and succession pathways and plan for replacement vegetation to achieve the desired future condition of the site (fig. 7.1).

Managers of developed sites must contend with the effects of forest disturbances on forest health and succession over time. Older trees are more likely to have decay, wounds, and defects that may compromise structural integrity. Some tree species are shorter lived and more prone to decay and may not be desirable in developed sites. Young, vigorous trees are often disease free, more wind firm, and have increased vigor to resist and recover from insect attacks, wounds, and diseases. When removing hazard trees or managing sites with older trees or undesirable tree species, replacement vegetation may be necessary to achieve the desired future condition of the site and should be selected in context with the local plant community, the silvics of the desired tree species, and local forest disturbance agents (e.g., root disease, dwarf mistletoe, bark beetles).

A vegetation management plan should "strike a balance between maximizing public safety, minimizing costs, and maintaining sustainability of the recreation resource." —Harvey and Hessburg (1992)

The primary goal of vegetation management planning is to achieve and maintain the quality of developed sites into the future. Vegetation management plans ensure that the vegetation in and around the site will: (1) be what is desired, (2) provide expected features, and (3) be sustainable into the future. Input by various resource specialists (e.g., recreation, silviculture, wildlife, heritage, fisheries, soils, fuels, forest pathology, entomology) is needed to create and implement a comprehensive vegetation management plan. A vegetation management plan may help inform the need for further analysis under the National Environmental Policy Act (NEPA).

Plan Components

- Develop objectives for the site (e.g., intended use, seasonality of use)
- Describe current conditions (e.g., tree species composition, site attributes like streams and lakes, forest health issues that contribute to hazards, cultural resources, and current wildlife uses)
- Describe short- and long-term desired conditions (e.g. maintain shaded campsites, create screening between campsites, promote desirable tree species)
- Design management actions to achieve desired conditions while considering regulatory limitations, such as operation windows that minimize impacts on wildlife (e.g., nesting, migration)
- Outline methods for implementation and monitoring

When To Develop a Plan

The best time to prepare a complete vegetation management plan is:

- When managing sites with chronic forest health issues, such as root disease, high incidences of stem decay, or severe dwarf mistletoe infestations
- When the scale of removal of hazard trees creates a need to consider and plan for replacement vegetation to achieve the desired future condition of the site
- When other vegetation management project boundaries encompass developed recreation sites
- Following a broad-scale tree mortality event (e.g., wildfire, bark beetle outbreak, drought, windstorm)
- Before selecting a site for development
- Before planning physical improvements for an existing site
- Before expanding an existing site

Templates and guidance for vegetation management plan development are available through your local forest health specialists.

Assessments Prior to Site Development

Hazard tree identification and long-range management strategies should be considered prior to selecting a site for development. This begins with a Tier 2 survey of the site prior to any capital improvement taking place. Carefully evaluate the presence of stem and root decays when considering current conditions. If root disease is detected, the site may need to be eliminated from further consideration, and the process to evaluate alternate sites initiated. Although mature stands are often more aesthetically appealing, they are often less suited for development due to their increased prevalence of tree defects, disease, and decay. Mature trees have large root systems that can be easily damaged when creating site access, vehicle parking, campsites, and other constructed features.

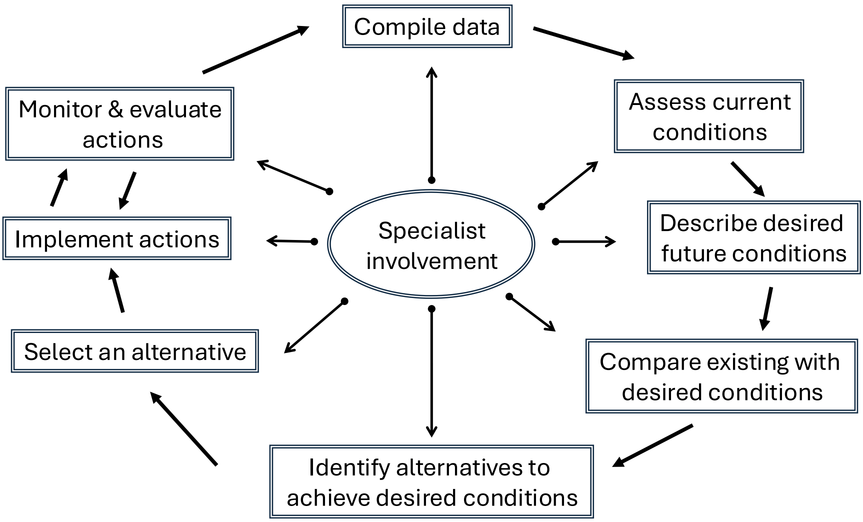


Figure 7.1—Components of vegetation management planning process.

CHAPTER 8

Tree Risk Assessments Following Large-Scale Disturbances

Large-scale disturbance events, such as those caused by wildfires (fig 8.1) and bark beetle outbreaks (fig. 8.2), can kill trees across thousands of acres in a short period of time. Often, due to the broad extent of these disturbances, there is an urgent need to efficiently and quickly reduce the risk from hazard trees and make these areas safer for personnel and the public. In these cases, a streamlined approach can be applied to tree risk assessments and hazard mitigation. However, the scale of these events also requires following National Environmental Policy Act (NEPA) processes (or other laws requiring consideration and disclosure of environmental effects) depending on the project's size, objectives, and predicted outcomes.

Figure 8.1—Large-scale roadside tree mortality caused by wildfire.

Figure 8.2—Lodgepole pine mortality along a road due to a mountain pine beetle outbreak.

The approach to identifying hazard trees following large-scale disturbance events differs from tree risk assessments detailed in previous chapters due to the scale of the problem and the uniformity of tree damage or mortality. Following large-scale disturbance events, there are known areas of potentially hazardous trees, and the workload focuses on prioritizing locations with targets within the disturbed area. In these situations, triage includes prioritizing the highest use sites or roads for surveys and mitigation.

A streamlined approach is possible because impact potentials and potential failure zones are constant. This approach is necessary because teams may only visit these areas once for surveys and mitigation. In this situation all trees will have the same impact potential rating, which allows a tree risk assessor to focus on the failure potential. Mitigation decisions can then be made based on failure potential ratings.

Angwin et al. (2022) developed a streamlined approach for assessing hazard trees in large-scale disturbance events that they describe as trying "to balance the urgent need for action, the large scale of areas impacted with a high number of hazard trees, the goal of retaining trees that are not immediate hazards, and the paramount objective of protecting agency staff and public safety. Balancing these numerous, and often competing, objectives is difficult and necessarily imperfect." The process outlined here is adapted from Angwin et al. (2022).

An Approach to Large-Scale Disturbance Events

Large-scale disturbance and tree mortality events necessitate an efficient tree risk assessment process:

1. Identify the project area
2. Identify the targets, establish the priorities, and define mitigation options
3. Select a potential failure zone distance and delineate the survey boundaries
4. Identify maximum acceptable failure potentials above which trees will be mitigated
5. Write a prescription for implementation

Identify the Project Area

The first action in designing a project after a large-scale disturbance is determining the spatial and temporal extent of the event and acquiring the necessary data to delineate the project area. For wildfires, this necessitates defining the fire perimeter(s). Additional fire severity information can be used to further prioritize within the project area.

Widespread insect-caused tree mortality, such as bark beetle outbreaks, can be more challenging to map due to the progressive spread and patchy distribution of tree mortality over the duration of the outbreak. The Forest Service's Forest Health Protection program and State cooperators conduct annual aerial detection surveys; these surveys and their data are useful to delineate where insect-caused mortality has occurred. Delineating project areas for other large-scale disturbance events (droughts, wind events, ice storms, etc.) would follow similar processes but may require other resources (e.g., remote sensing tools). Contact a forest health specialist for more information.

Identify the Targets, Establish the Priorities, and Define Mitigation Options

Once the project area is delineated, the affected infrastructure (i.e., targets) should be identified, mapped, and prioritized for survey and mitigation efforts. Prioritization may consider infrastructure value, vegetation conditions, frequency and duration of employee and public use, need for immediate access, availability of funds and workforce, and other factors. Refer to the "Prioritizing Survey Areas" and subsequent sections in chapter 1 for more information.

The prioritization of targets may be reevaluated if there are changes in conditions, budgetary constraints, or implementation is delayed. Depending on the scope and scale of the disturbance event, mitigation actions will vary by priority and target type and may not be possible or feasible in all areas.

Planning teams should create distinct rankings for identified targets. Since roads and infrastructure often cross State and Federal lands, planning teams should consult with other jurisdictions in the prioritization process where appropriate. Planning teams should also consider both normal planned work and rehabilitation work when establishing priorities. Prioritization entails comparison of multiple, sometimes competing interests, and relative rankings will differ by area.

Wildfires often leave a mix of burn severities on the landscape, which causes differences in timing and levels of tree mortality or changes in tree structural stability—factors that impact the prioritization of areas for survey and mitigation. A fire may kill all trees in one area while trees in another area survive, creating patches of mortality on the landscape. Depending on forest type, delayed tree mortality may also be common in low to moderate burn severities. Knowledge of vegetation conditions via remote sensing tools and ground data will help prioritize areas for survey and mitigation.

Exploring viable mitigation options should also be part of the planning process. Mitigation can include felling hazardous trees (fig. 8.3); closing or restricting access to areas (fig. 8.4); posting warnings of known hazards at access points to the disturbed area (e.g., roads and trailheads); or posting information of known hazards on websites, user permits, or other publicly available resources. Mitigation in high-priority areas should occur first, and closing access to these areas may be warranted until mitigation is completed. In low- and medium-priority areas, the use of targeted closures, signage, or change in use patterns may reduce the risk to an acceptable level.

Figure 8.3—Hazard tree mitigation in a campground after a fire.

Figure 8.4—A road closure after a fire.

Select a Failure Zone Distance and Delineate the Survey Boundaries

Failure zones of 1 to 1.5 times or more of individual tree height can be considered during project planning and will be based on factors such as topography, desire to retain trees that might be valuable for wildlife, the use patterns of the area (seasonal vs. year-round), and duration and frequency of exposure. **In general, one tree height suffices as the potential failure zone for surveys on flat ground.** In some areas, the failure zone can be set at the average or maximum tree height. The selected, generalized failure zone is used in both delineating the survey area boundary and writing the prescription.

Once a standard for failure zone is established, the survey area can then be delineated and mapped using a generalized potential failure zone. The survey area specifies the zone within the full project area where hazard trees will be assessed and designated for mitigation in subsequent actions. The purpose of designating a general survey and mitigation area within the project area is to focus hazard tree identification and mitigation efforts within a discrete area. Using GIS, teams can quantify the number of acres or miles of road that will be surveyed, establish survey and potential mitigation area boundaries, and assess environmental effects. This should accelerate hazard tree identification and mitigation.

Identify the Failure Potentials Requiring Mitigation

Planning teams will need to determine a maximum acceptable failure potential above which trees will require mitigation. In general, the tree defects outlined in Tier 1 surveys (table 4.1) will be appropriate for tree risk assessments after large-scale disturbances. Typically, trees with failure potential of 4 or greater in a Tier 1 survey are candidates for mitigation. Occasionally, a combination of live and dead maximum acceptable tree failure potentials can be determined within a survey area (e.g., mitigate all dead trees, as well as live trees with defects that have a failure potential of 5). The prevalence of preexisting defects will depend on multiple factors, such as forest type and age. For example, older forests will tend to have snags, trees with substantial stem decay, and other structural defects such as bole cracks. Not all trees within a survey area will need to be mitigated. Mitigation is only necessary for those trees that exceed the defined maximum acceptable failure potentials.

Additional Considerations in Selecting Maximum Acceptable Failure Potentials

Dead tree management practices and potential delayed tree mortality are important factors to consider during surveys and mitigation. This can include requirements for an area to retain certain densities or sizes of dead trees (based on the appropriate land management guidance), as well as considering where retention of dead trees will have the lowest risk, the feasibility of multiple entries for surveys and mitigation, and project viability if repeated entries are warranted.

Teams can plan for assessors to rate dead trees following guidance for Tier 1 assessments using table 4.1. Additional guidance is in the “Recommendations for Dead Trees” section in chapter 4 and the associated failure potentials in table 4.5—this is useful when there is a desire or requirement to retain dead trees on a landscape after a large disturbance. However, using table 4.5 to rate dead trees may require a more detailed prescription than the streamlined dead tree rating system in table 4.1. Retaining dead trees in areas with lower exposure or low-value targets is more practical than areas with higher exposure or high-value targets.

Another challenge is deciding whether to mitigate trees that are not currently above the maximum acceptable failure potential selected but are likely to become hazards in the next few years—trees may continue to die for several years following a large-scale disturbance event. This adds to the complexity of project planning for hazard tree removal. Waiting for trees to become hazards presents at least three problems for land managers:

- Not all dead trees have very high failure potentials (tables 4.1, 4.2, and 4.5); however, trees become more dangerous to mitigate over time because of increased decay and defects. This increases the risks to workers, visitors, and other users.
- Repeated entries to capture delayed morality as it occurs can be costly and cause additional resource damage. Alternatively, a single entry with the objective of removing trees that are likely to become hazards may be more cost-efficient and have less impact on other resources, but risks removing trees that may not become hazardous.
- Dead trees lose commercial value over time. The timing of mitigation and how it relates to commercial value and associated project costs may be an additional consideration. If trees have commercial value, it may help offset project costs.

Removing trees that are likely to have delayed mortality after a large-scale disturbance can reduce the need for multiple entries to a site. Assessment of tree status after a fire and associated marking guidelines, such as those established by Hood et al. (2021) for the Pacific Northwest, can be used to determine mitigation priorities. It is important to note that the Hood et al. (2021) tree status assessment guidelines are only appropriate for use through the second winter after a fire; after that, crown injuries become less apparent, making assessment more difficult. Local forest health specialists (e.g., entomologists) can be contacted to provide guidance on the probability of mortality following fires and bark beetle outbreaks.

Writing the Prescription for Implementation

Once the project area is defined, targets are identified, priorities are set, a failure zone is established, survey areas are delineated, and a maximum acceptable failure potential is selected, a prescription outlining the criteria for implementation can be written. A prescription defines the parameters of the tree risk assessment and mitigation project, confers that information to land managers, employees, and contractors, and provides the necessary documentation for decision making under NEPA or other environmental laws requiring consideration and disclosure of environmental effects. A prescription should be tailored to individual units within a larger project, thus creating marking guides that may differ for each unit within a larger project. The criteria then can be condensed to include failure zone distance and the maximum acceptable failure potentials for trees to be mitigated.

Example Scenario

The road in this example was prioritized for tree risk assessments because it provides year-round access and egress for 50,000 residents and visitors and has high traffic volumes. Smaller, arterial roads open seasonally were not prioritized for assessments at this time due to resource and personnel constraints. The prioritized road is now within the footprint of a recent, high-severity fire. Due to the year-round use and high traffic volume, the failure zone is set to 1.5 times the tree height upslope from the road and one tree height downslope. Trees with greater than 15 degrees lean away from the road, regardless of failure potential, will not be cut since the failure zone of the tree does not include the road. Mitigation is decided as removing (i.e., cutting) trees within the survey area that exceed the maximum acceptable failure potential (FP).

Mitigation Prescription

Dead trees—Remove trees with no green needles (all dead trees; planning team used table 4.1 with a FP >4).

Remove live trees:

- with greater than 50 percent of the bole cross-sectional area burned and consumed or at least two quadrants of burned and consumed structural roots (FP ≥4)
- with less than 50 percent of the structural roots remaining in the ground (FP ≥3)
- leaning toward the road with freshly disturbed soil or that are root sprung (FP = 5)
- leaning more than 15 degrees toward the road with evidence of decayed roots without disturbed soil (FP = 4)
- with open or sealed structural bole cracks with evidence of decay or evidence of active failure (FP ≥4)

Implementing the Prescription

Assessments may be done on an individual tree basis or by groups of trees by a marking crew or the purchaser/logger/operator in “designation by prescription” situations. Given the scale and uniformity associated with most hazard tree mitigation after a large-scale disturbance, individual tree evaluation and documentation processes are generally not practical or necessary. For instance, in an area with homogenous conditions across a broad landscape—such as a severe fire resulting in 100 percent mortality—it may be known that all trees in that area are dead. Therefore, an individual assessment of each tree’s failure potential would not be necessary. Similarly, an individual assessment of each tree’s potential failure zone may not be necessary when the target is clearly within the failure zone of a group of trees. However, a tally or cruise of trees and a general written description of the types of tree defects that were encountered should be completed for tracking and accountability when individual tree assessments are not completed, whether this is through tree marking or designation criteria (e.g., “145 dead lodgepole pines with 8- to 10-inch diameters flagged for removal between mile markers 201 and 204 on Forest Service Road 480”).

In reality, tree risk assessments after a large-scale disturbance event will likely be a combination of group assessments across large areas of trees (such as all fire-killed trees as discussed above) with individual tree assessments to remove trees with appropriate structural defects and trees likely to have delayed mortality. Planning teams should include silviculturists, foresters, and timber sale preparation experts for issues such as risks to and from residual trees following large-scale treatments and proper fuels maintenance.

Tree failure after bole consumption by fire in tree with preexisting decay column.

APPENDIX 1

Disease and Defect Identification

This appendix builds on the defects outlined in chapter 4 and describes in more detail common tree diseases that cause structural defects and contribute to tree failure. The diseases listed are common to the Pacific Northwest region of the United States—though some are found throughout North America and beyond—and are organized by root and butt diseases, heartwood decays (heart rots), sapwood decays (sap rots), fungal cankers and stem rusts, and other damaging agents common to forest trees. Refer to Goheen and Willhite (2021), as well as other materials listed in the "References and Background Material" section, for information on diseases not listed here.

Root and Butt Diseases

Root and butt diseases are associated with a high percentage of tree failures in developed sites across the Pacific Northwest. Most root diseases are caused by fungal pathogens that decay roots and butts, which reduce structural integrity, root anchorage, and tree vigor. The most conspicuous impacts of root and butt diseases on their hosts are predisposition to death, wind breakage, windthrow, and attack by bark beetles. In the Pacific Northwest, the three most common root diseases are laminated root rot, Heterobasidion root disease, and Armillaria root disease.

Proper diagnosis of the causal agent is important because tree failure potential can vary considerably depending on which pathogen is involved. Also, the occurrence and severity of each disease differs by host (table A1.1), geographic location, and site condition. Unfortunately, root and butt diseases and resulting defects are often difficult to detect. While some trees exhibit readily visible, aboveground signs and symptoms, many more may be diseased with limited or no aboveground indications.

Symptoms can be subtle, and many indicators of colonization and decay, especially in the early stages of disease, are located either underground where they cannot be seen without substantial root excavation or inside lower basal and butt stem sections where drilling is necessary for evaluation. Because of this, root diseases often go undetected until trees fail and reveal decayed roots or hollow butts. Many root pathogens can survive for decades in old, infected roots; it is extremely important to document the presence of root diseases in developed sites, since they will likely remain a significant concern far into the future.

Individual tree and site-level symptoms and signs of root diseases include:

- General decline of the entire live crown characterized by chlorosis (i.e., yellowing) of foliage, thinning crown, and growth reduction of terminal and, eventually, lateral shoots (fig. A1.1)
- Stress cone crops (prolific, often smaller-sized cones on trees with other crown symptoms (fig A1.1))
- Basal resinosis (fig. A1.2) or bark staining (fig. A1.3)
- Decayed wood at base (i.e., butt rot), sometimes extending 30–35 ft up the stem
- Mushrooms or conks of root pathogens at root collars, in stumps (fig. A1.4), or on the ground near the base of the tree
- Pathogenic fungal mycelia on, in, or under the host bark in the roots and root collar.
- Windthrown trees with decayed roots (fig. A1.5)
- Early or advanced wood decay within stumps
- A progression of dead, dying, and declining trees in discrete areas or pockets within the stand (fig. A1.6)

Figure A1.1—Thinning Douglas-fir crowns with stress cone crops caused by laminated root rot.

Figure A1.2—Basal resinosis on a tree.

Figure A1.3—The base of a Douglas-fir with bark staining, characteristic of infection by laminated root rot.

Figure A1.4—Heterobasidion conks in a decayed stump.

Figure A1.5—Advanced root disease compromises the structural roots and leaves trees susceptible to windthrow.

Figure A1.6—Pockets of dead and dying trees within a stand are indicative of root diseases.

Armillaria Root Disease

Causal agent—*Armillaria* spp.

Hosts and distribution—Armillaria root disease (ARD) occurs on most tree species throughout Oregon and Washington (table A1.1). *Armillaria* species can affect hosts differentially, depending on the area, as either weak pathogens of stressed, low-vigor trees or as aggressive tree killers.

As general rules:

1. Infection of stressed or injured conifers is most likely on highly productive coastal sites and areas west of the Cascade Mountains, while aggressive tree killing is more common in the Cascade Mountains of southwest Oregon and east of the Cascade Crest in Oregon and Washington.
2. True firs are the most highly susceptible conifer hosts of ARD, interior Douglas-firs are susceptible, and other conifers are usually more tolerant or resistant.
3. Tree susceptibility to ARD can differ markedly by location. For example, pines can be severely damaged in southwestern Oregon, south-central Washington, and northeastern Washington.
4. *Armillaria* species that cause root disease often occur in combination with other root disease fungi, especially *Coniferiporia sulphurascens, Heterobasidion occidentale, Leptographium pseudotsugae,* and *Phaeolus schweinitzii*.
5. Some *Armillaria* species may infect hardwoods and are commonly associated with summer irrigation or flooding, especially with the Oregon white oak.

Identification—Characteristic patterns of mortality may be observed where ARD is present. In the aggressive tree-killing case, dead and dying trees of susceptible host species will be situated in and around disease centers that exhibit evidence of outwardly expanding tree mortality that has occurred over many years (see fig. A1.6). Infection centers can be very large. In cases where *Armillaria* is affecting low-vigor and stressed hosts, infected trees may appear as scattered individuals or small groups of dead and dying trees, often clearly associated with such stress factors as wounding, compacted soils, off-site plantings, drought, infection by other disease organisms, bark beetle attacks, or fires.

ARD is usually easier to recognize than Heterobasidion root disease (HRD) or laminated root rot (LRR). Infected trees express typical root disease crown symptoms, including a thinning crown, foliage chlorosis, and formation of stress cone crops (see fig. A1.1). Additionally, basal resinosis (i.e., resin flow or bark staining at the base) may be present at and above the root collar (see fig. A1.2). Resin-soaked, decayed wood is often shredded in the butt and roots.

To confirm the presence of *Armillaria*, chop into the root collar of a declining or recently dead tree to check for white, latexlike mycelial fans just under the bark (figs. A1.7 and A1.8). Thick mycelial fans that extend above the ground are considered diagnostic of pathogenic ARD, which is actively killing the tree, especially when associated with heavy resin flow. Thinner mycelia that can be easily rubbed off do not indicate that ARD is directly killing the tree. Rhizomorphs (i.e., shoestring like, often branching, hyphal structures) may be found under the bark of infected trees or on roots, and honey-colored mushrooms may form at the bases of infected trees in autumn (fig. A1.9). However, neither indicate that *Armillaria* is actively killing the tree.

Importance—Unlike LRR and HRD, ARD frequently causes tree mortality prior to failure. Infected trees are frequently infested by bark beetles. Though some root decay occurs, trees generally die standing, and windthrow prior to death is not as common as with LRR and HRD.

Fungi that cause ARD can survive as saprophytes in dead host material for at least 50 years. Spread to adjacent host trees occurs as mycelia or rhizomorphs grow across root contacts at a rate of 1–2 feet per year. The failure potential of trees in and around ARD centers varies depending on tree species, presence of signs and symptoms, and the presence of adjacent windthrown trees with the same root disease (table 4.2).

Figure A1.7—Mycelial fans under bark confirm the presence of *Armillaria* species.

Figure A1.8— Basal pitching is a symptom of the host tree and mycelial fans under the bark are signs of *Armillaria* species.

Figure A1.9—Armillaria mushrooms at the base of an infected tree.

Black Stain Root Disease

Causal agent—*Leptographium ponderosum* (formerly *L. wageneri* var. *ponderosum*) and *L. pseudotsugae* (formerly *L. wageneri* var. *pseudotsugae*))

Hosts and distribution—All ages of ponderosa pines in isolated locations east of the Cascade Crest in Oregon can be killed by *Leptographium ponderosum*, and young Douglas-firs west of the Cascades are commonly killed by *L. pseudotsugae*. Other conifer species are rarely affected (table A1.1).

Identification—Infected trees express typical crown symptoms of other root diseases (e.g., chlorosis, thin crown, stress cones). The diagnostic sign for black stain root disease (BSRD) is a brown to purplish-black stain in older sapwood (fig. A1.10) that fades with time in dead trees. Heavy resin flow and resin soaking at the base of the tree may also be present. This disease is not associated with decayed tree butts or roots.

Importance—The disease is a vascular wilt that causes tree mortality but not root decay. BRSD spreads from tree-to-tree across root contacts. Long-distance spread occurs via root-feeding bark beetles and weevils that are attracted to stressed trees and vector inoculum of *Leptographium* spp. when they feed on the roots. BSRD is often associated with soil disturbance along roads, soil compaction, and large numbers of injured host trees.

BSRD has been infrequently found in developed sites in the Pacific Northwest and is not nearly as common as LRR, ARD, or HRD. Because BSRD does not cause root decay, affected trees die standing; refer to the "dead trees" row of table 4.2 to rate the failure potential of trees killed by BSRD.

Figure A1.10—Diagnostic staining in the sapwood of a Douglas-fir caused by black stain root disease.

Ganoderma Root and Butt Rot (White Mottled Rot)

Causal agent—*Ganoderma oregonense* and *G. applanatum*

Hosts and distribution—*Ganoderma oregonense* occurs throughout Oregon and Washington primarily on hemlocks, true firs, and spruces, and occasionally on Douglas-firs and pines (table A1.1). *G. applanatum* occurs on Douglas-firs, hemlocks, pines, spruces, true firs, western redcedars, and, unlike *G. oregonense*, hardwoods.

Identification—*Ganoderma oregonense* (common names include varnish conk and lacquer fungus) occurs only on conifers and forms a distinctive conk that is annual, stalked, reddish brown, and shiny as if lacquered or varnished (fig. A1.11). *Ganoderma applanatum* (common name: artist's conk) produces perennial conks that are leathery to woody and occasionally stalked with a tan upper surface and a white to creamy undersurface that is easily bruised (fig. A1.12). Decay associated with both species is a white spongy rot with black specks.

Importance—Decay by *Ganoderma* spp. occurs predominately in dead trees, but occasionally live trees with wounds can be infected and decayed. The failure potential for live trees with Ganoderma root and butt rot depends on the extent of butt decay. *G. applanatum* is very common on live Oregon myrtle (*Umbellularia californica*) in southwest Oregon and impacted trees should be inspected for cavities and evidence of butt rot. Use the sound rind thickness tables (tables 4.3 and 4.4) and tree defects table (table 4.2, see "butt rot" row) to determine the failure potential of infected trees.

Figure A1.11—*Ganoderma oregonense* conks have a lacquered, or shiny, upper surface appearance.

Figure A1.12—*Ganoderma applanatum* conks have a tan upper surface and a creamy-white pore surface.

Heterobasidion Root Disease and Butt/Stem Decay

Causal agent—*Heterobasidion occidentale* (formerly *H. annosum* "fir type") and *H. irregulare* (formerly *H. annosum* "pine type"); formerly referred to as annosus root disease

Hosts and distribution—Most conifers are susceptible, but susceptibility and damage vary by species and location (table A1.1). *H. occidentale* is distributed throughout Washington and Oregon and primarily infects true firs, hemlocks, and spruces. *H. irregulare* is found primarily in dry areas east of the Cascade Mountains and infects pines and junipers.

Identification—Heterobasidion root disease (HRD) can occur in single trees or in groups of susceptible trees but does not always occur in discrete centers. Individual trees may be infected with few to no indicators, especially for species that predominantly experience butt rot. Alternatively, infected trees may occur in small infection foci centered around old, infected stumps or wounded trees, or in large infection centers where tree-to-tree spread has occurred for many decades.

Infected trees (especially true firs, pines, and junipers) may exhibit crown symptoms like those caused by other root diseases, including thinning crowns, needle chlorosis, growth reduction, and crown dieback prior to death (see fig. A1.6). Hemlocks that develop only butt and stem decay rarely show crown symptoms prior to failure, and drilling at the base of trees can confirm the presence of decay.

The fruiting bodies, or conks, are perennial with a woody or leathery upper surface that is black to chestnut brown with white, poreless margins, while the undersurface is creamy white with small, round, irregular-shaped pores (fig. A1.13). Conks may be found in old stumps, wounds, in root crotches of living trees, and belowground on roots of living or dead hosts. Young conks on roots are small, white to buff pustules. The presence of a conk on a tree or stump proves infection, however many *Heterobasidion*-infected trees do not produce conks. The presence of a conk on a tree or in a stump indicates that adjacent host trees have a high probability of being infected.

Incipient decay caused by *Heterobasidion* species is a light-brown to reddish stain in the heartwood. Advanced decay is often white, spongy, and wet (fig. A1.14) or delaminated (fig. A1.15) with elongated pits on only one side of the sheet and no setal hyphae. The absence of setal hyphae helps to distinguish HRD from LRR. Because HRD is often the most difficult root disease to diagnose, managers and tree risk assessors can seek assistance from forest pathologists when they suspect HRD.

Importance: HRD causes progressive root and butt rot that contributes to windthrow or stem breakage. Generally, extensive root and butt decay and mortality by *H. occidentale* is common for grand and white firs, and fir engravers commonly infest infected trees. Older spruces, hemlocks, and true firs may have substantial root and butt rot due to *H. occidentale* infection. On drier sites (e.g., east of the Cascade Mountains), ponderosa pines and junipers may be infected, decayed, and killed due to *H. irregulare*.

Both *H. occidentale* and *H. irregulare* are spread over long distances by windborne spores that land on and infect fresh wounds and newly created stumps of host tree species (table A1.1). Once infected, the pathogen grows into the roots and begins causing decay. Underground spread of the disease occurs across root contacts between infected and noninfected hosts at a rate of 1–2 feet per year. *H. occidentale* and *H. irregulare* can remain viable in infected stumps and roots for decades after tree death, especially in very large stumps. As with other root diseases, HRD is considered a disease of the site, and management actions should account for the presence of inoculum on a site.

When HRD is confirmed in a developed site, live trees in and around disease centers vary in failure potential depending on geographic area, tree species, and presence of signs and symptoms of HRD (table 4.2). The presence of adjacent windthrown trees with evidence of root disease is an indicator of increased failure potential.

Heterobasidion species can act as stem decays, sometimes high in the tree associated with wounding, and predispose trees to windthrow and breakage. If conks are found on the butt or higher on the tree, check sound rind thickness at conks where possible for a more accurate estimation of decay.

Figure A1.13— Heterobasidion conks have dark-brown upper surfaces with a noticeable white margin.

Figure A1.14—White, spongy decay caused by *Heterobasidion occidentale* within an infected root.

Figure A1.15—Delaminated decay caused by *Heterobasidion occidentale* at the base of an infected tree that failed due to Heterobasidion root disease.

Laminated Root Rot and Cedar Laminated Root Rot

Causal agent—*Coniferiporia sulphurascens* and *Coniferiporia weirii* (formerly *Phellinus weirii*)

Hosts and distribution—Laminated root rot (LRR), caused by *Coniferiporia sulphurascens*, is widely distributed and common across Washington, western Oregon, and eastern Oregon north of the Crooked River. All conifers may be infected, but overall susceptibility and damage vary by species (table A1.1). Douglas-firs, mountain hemlocks, and white and grand firs are readily infected, extensively decayed, and often killed by *C. sulphurascens*. Other conifers can tolerate or resist infection and damage to varying degrees. Larches, spruces, and western hemlocks may develop substantial butt rot. Pines and cedars are rarely infected, but some root colonization can occur. Hardwoods are immune to *C. sulphurascens*. Cedar laminated root rot, caused by *Coniferiporia weirii*, occurs primarily on western redcedar, but may also infect Alaska yellow-cedar.

Identification—LRR often occurs in discrete centers that are frequently characterized by an abundance of windthrown trees with only stubs of roots remaining (fig. A1.16). This pattern is often less apparent in developed sites due to previous tree removals. Infected hosts exhibit characteristic root disease symptoms, including thinning crowns, foliar chlorosis, growth decline, stress cone crops, and basal resinosis, especially once half or more of their roots have been affected. However, some infected trees do not exhibit crown symptoms.

Delaminated decay (i.e., decay that separates into sheets along the annual growth rings) with elliptical pits on both sides of the sheet is usually evident in roots or stumps of infected trees with advanced decay (fig. A1.17). Tufts or mats of reddish-brown setal hyphae between the sheets of decayed wood are diagnostic of *C. sulphurascens* (fig. A1.18). A hand lens is helpful for confirming the presence of setal hyphae. Ectotrophic mycelium may occur on the bark of infected roots as a grayish-buff, crusty sheath that cannot be readily rubbed off (fig. A1.19). Ectotrophic mycelium often contains tufts of setal hyphae. Flat, buff-colored or darker conks, which may appear crustlike, may also be present, but these have little diagnostic value as they are uncommon.

A crescent-shaped stain persists on a fresh-cut stump surface immediately after falling (figs. A1.20 and A1.21). Hollows or crescent-shaped areas containing advanced decay may occur. Old cut stumps in long-established recreation sites with frequent removal of dead and windthrown trees should be examined for *C. sulphurascens* decay as they are often the only indicators of historic disease presence on the site.

Importance—LRR is the most damaging root disease of conifers in Oregon and Washington and poses a significant hazard to people and property. Roots of highly susceptible hosts may be extensively decayed, leading to windthrow and mortality. Extensive butt decay may also contribute to reduced structural stability at the base. Windthrow of living, nonsymptomatic trees frequently occurs in highly susceptible hosts. This makes LRR particularly dangerous in developed sites. More tolerant hosts, such as the western hemlock, that develop butt rot may break at the butt or lower stem as decay advances.

Both species can remain viable in dead, infected roots for more than 50 years. The fungus spreads from infected roots of both live and dead trees to new susceptible hosts via ectotrophic mycelium (see fig. A1.19). The rate of spread is about 1 to 2 feet per year. This progression leads to gradually expanding infection centers in stands with continuous distributions of susceptible hosts.

Trees in and around root disease centers vary in failure potential depending on presence of signs and symptoms, species, and location relative to adjacent diseased trees or stumps. Given the history of damaging failures due to LRR in recreation sites in the Pacific Northwest, the unpredictable nature of these failures, and the difficulty detecting the disease, LRR should be of particular concern in developed sites.

Figure A1.16—Decayed and missing structural roots on windthrown trees are a common result of laminated root rot.

Figure A1.17— Characteristic decay caused by *C. sulphurascens* in which the wood is delaminated into separate sheets along the growth rings.

Figure A1.18— Tufts of brown or reddish setal hyphae on decayed wood is diagnostic of laminated root rot.

Figure A1.19—Ectotrophic mycelium of *C. sulphurascens* on the outside of an infected root.

Figure A1.20—Staining and visible decayed wood associated with laminated root rot in a cut stump.

Figure A1.21—Crescent-shaped staining can be present on fresh-cut stump surfaces immediately after falling.

Port-Orford-Cedar Root Disease

Causal agent—*Phytophthora lateralis*

Hosts and distribution—Port-Orford-cedar and occasionally Pacific yew in southwest Oregon and occasionally where ornamental Port-Orford-cedar occurs.

Identification—Progressive discoloration of foliage from yellow to bright red to red brown and then brown occurs as the disease progresses. The diagnostic symptom is a cinnamon-colored stain in the inner bark of roots and lower stems (fig. A1.22). This disease is not associated with decayed tree butts or roots.

Importance—Port-Orford-cedar root disease is caused by *Phytophthora lateralis,* a nonnative pathogen that causes cambial death and subsequent tree mortality but not decay. This disease is common along roads, watercourses, and in poorly drained areas. As with BSRD, affected trees die standing and should be rated for failure potential using the "dead trees" row in table 4.2.

Figure A1.22—Cinnamon-colored staining on the inner bark of a Port-Orford-cedar from *Phytophthora lateralis*.

Schweinitzii Root and Butt Rot

Causal agent—*Phaeolus schweinitzii*

Hosts and distribution—Most conifer species throughout Oregon and Washington are susceptible to infection and decay, with Douglas-firs being most frequently affected, especially old, large trees. Western larches, Engelmann spruces, Sitka spruces, and lodgepole, ponderosa, western white, and sugar pines are also commonly infected. Other conifers are occasionally infected (table A1.1).

Identification—*Phaeolus schweinitzii* produces conspicuous fruiting bodies on the ground near or growing on the base of infected trees. Due to the appearance of these annual conks, *P. schweinitzii* is referred to as "velvet-top fungus" or "cow-pie fungus." Fresh conks occur in the fall, have a velvety texture, and have brightly colored yellow margins (fig. A1.23). Old conks turn brown (resembling a cow pie) and persist for a few years (fig. A1.24). On the east side of the Cascade Range, infection and decay may be as common as on the west side, but conks are less common.

As infections and subsequent decay progress, the butt of the tree may swell. Advanced decay is a brown cubical rot. Butt decay can extend 30 feet up the tree on old trees (>150 years). Trees with butt rot often fail under high-wind conditions, leaving a characteristic barber chair and shattered butt (fig. A1.25).

Importance—Schweinitzii root and butt rot is one of the most common causes of conifer failure in developed sites across Oregon and Washington, especially for old, large Douglas-firs, ponderosa pines, western larches, and Stika spruces. Trees may become infected by this pathogen at any age. Fresh trunk wounds caused by mechanical injury or fire are probably not infected directly by spores, but the wounds exacerbate decay in previously infected roots and butts.

On the west side of the Cascades, damage most often occurs in Douglas-firs and Sitka spruces over 150 years old (table A1.1). On the east side, Douglas-firs, western larches, ponderosa pines, and lodgepole pines over 100 years old are frequently damaged. In southwest Oregon, old Douglas-firs, ponderosa pines, and sugar pines are frequently decayed.

When conks or other indicators are less common, schweinitzii root and butt rot can often be overlooked until failures have occurred, usually from significant wind events. Failed trees generally have a sound rind thickness well below the thresholds in tables 4.3 or 4.4. Additionally, the presence of significant decay in roots and butts is not always indicated by the presence of *P. schweinitzii* conks and vice versa, even west of the Cascade Range where conks are common. Instead, a single fruiting body warrants closer examination of the infected tree as well as any immediately adjacent susceptible hosts.

When schweinitzii root and butt rot is encountered in developed sites, trees should be thoroughly evaluated rather than automatically removed. Evaluators should assess the infected trees for obvious leans, recent root pulling or partial failure, wounding, butt swell, cracking of the butt, and evidence of carpenter ant or termite activity in the butt. Suspect trees (i.e., those with conks) should be drilled near the root collar to determine sound rind thickness (tables 4.3 and 4.4). Additionally, each of the major lateral roots should be exposed and drilled within 2 ft of the root collar to detect any decay or hidden defect in the roots that provide anchorage. If most of the major roots are not decayed and there is minimal butt decay, the tree may be retained and monitored every few years depending on the extent of defects and decay.

Monitoring trees with this disease includes annual inspections for any newly formed cracks, new leans, root pulling, etc. Once the sound rind thickness at the tree's base and structural roots has been assessed, frequency of drilling of monitor trees should be based on proximity to sound rind thresholds (e.g., a tree with 45 percent sound rind likely will not need to be drilled again for 7–10 years as this decay develops very slowly), unless there has been a change in condition. Trees with seriously compromised anchorage and inadequate sound rind thickness pose a hazard and should be mitigated. To determine the failure potential of trees with schweinitzii root and butt rot, refer to the "butt rot" row in table 4.2.

Figure A1.23—Fresh *Phaeolus schweinitzii* conks with a velvety texture and cream to yellow margins.

Figure A1.24—Old *Phaeolus schweinitzii* conks are darker brown, can be brittle, and have no yellow margins.

Figure A1.25—Tree failures caused by *Phaeolus schweinitzii* often occur at the butt and have visible brown cubicle decay.

Tomentosus Root And Butt Rot

Causal agent—*Onnia tomentosa* and *O. subtriquetra*

Hosts and distribution—Engelmann spruce is the most common host in Oregon and Washington (table A1.1). Occasional hosts include the Sitka spruce, Pacific silver fir, grand fir, white fir, lodgepole pine, ponderosa pine, and Douglas-fir. Tomentosus root and butt rot may be important in certain areas.

Identification—Tomentosus root and butt rot can be difficult to detect, as even trees with extensive butt rot may not exhibit crown symptoms prior to failure. Further, this disease often does not occur in discrete centers like LRR or ARD. When present, tomentosus root and butt rot can be identified by small, yellow to cinnamon leathery conks near the bases of infected trees in the fall (fig. A1.26). Even where infection and decay are common, fruiting bodies are seldom produced in some localities, especially in the Blue Mountains. Incipient decay in spruce roots has a reddish-brown color that can be detected by drilling. Advanced decay is a white pocket rot that can take on a honeycombed appearance (fig. A1.27). Ectotrophic mycelia may occur but should not be used to diagnose any specific root disease since multiple root diseases produce surface mycelia.

Importance—The infection and spread of tomentosus root and butt rot is like that of HRD. Inter-tree spread occurs via an ectotrophic mycelium, and spores are involved in infection of wounds and freshly cut stumps. Failures due to windthrow or wind shattering of severely decayed butts of mature trees are common (fig A1.28).

Spruces with high-value targets in the failure zone should be checked for external indicators of decay (e.g., conks, wounding). If a spruce has an external indicator of decay, it should be drilled and failure potential determined using the "butt rot" row in table 4.2 along with the sound rind thresholds in tables 4.3 and 4.4.

Figure A1.26—Small leathery conk of *Onnia tomentosa*.

Figure A1.27—Honeycombed decay caused by *Onnia tomentosa*.

Figure A1.28—Failure of Engelmann spruce caused by *Onnia tomentosa*.

Yellow Root Rot (Stringy Butt Rot)

Causal agent—*Perenniporia subacida*

Hosts and distribution—*Perenniporia subacida* is widespread in Oregon and Washington where it causes tree mortality and butt rot in suppressed or stressed trees, especially Douglas-firs, true firs, and western hemlocks, as well as many hardwood species (table A1.1).

Identification—*Perenniporia subacida* produces white, crustlike or leathery conks that are flattened against the wood or bark on the undersides of roots, logs, fallen trees, or exposed roots. These conks turn cream to yellow orange with age. Early decay is a light-brown stain that resembles wetwood. Advanced decay is composed of irregularly shaped pockets of decayed wood that coalesce into masses of stringy fibers with black flecks. Infected hosts may exhibit delaminated decay. Yellow-white mycelial mats may form between the delaminated sheets of wood (fig. A1.29).

Importance—Affected trees may be easily windthrown, depending on the extent of root and butt decay. The disease is difficult to detect in live trees as signs and symptoms typically occur belowground. Failure potential primarily depends on the extent of butt decay (refer to the "butt rot" row in table 4.2).

Figure A1.29—Advanced decay and yellow-white mycelial mats of *Perenniporia subacida*.

Table A1.1—Frequency of occurrence by host species of root and butt diseases in Oregon and Washington

Host species		Armillaria root disease (ARD)	Black stain root disease (BSRD)	Ganoderma root and butt rot	Heterobasidion root disease (HRD)	Laminated root rot (LRR)	Port-Orford-cedar root disease	Schweinitzii root and butt rot	Tomentosus root and butt rot	Yellow root rot
Alder		3		3	4					3
Aspen		2		3						
Ash				3						
Birch		3		3						3
Cedars	Alaska	3		3	3	4		3		
	Incense	3			3	4				
	Port-Orford	3			3	4	1			
	Western red	2		3	2	3		3		3

Host species		Armillaria root disease (ARD)	Black stain root disease (BSRD)	Ganoderma root and butt rot	Heterobasidion root disease (HRD)	Laminated root rot (LRR)	Port-Orford-cedar root disease	Schweinitzii root and butt rot	Tomentosus root and butt rot	Yellow root rot
Cottonwood		2		3	3					3
Douglas-firs	Coast	2	1	3	3	1		1	4	3
	Inland	1	3	3	3	1		1	4	3
Hemlocks	Mountain	2	3	2	1	1		3		3
	Western	2	3	2	1	2		3		3
Juniper		3			3	4				
Larch		3			3	2		1		3
Madrone		3			2					3
Maple		3		3	4					3

Host species		Armillaria root disease (ARD)	Black stain root disease (BSRD)	Ganoderma root and butt rot	Heterobasidion root disease (HRD)	Laminated root rot (LRR)	Port-Orford-cedar root disease	Schweinitzii root and butt rot	Tomentosus root and butt rot	Yellow root rot
Myrtle				3						
Oak		2		3	4			3		
Pines	Jeffrey	2	3	3	2	3		2	3	
	Lodgepole	3	3	3	2	3		2	3	3
	Ponderosa	2	2	3	2	3		2	3	
	Sugar	2	3	3	3	3		2		
	Western white	2	3	3	3	3		2		
	Whitebark	3	4	3	3	3		2		
Redwood		3			3	4		3		

Host species		Armillaria root disease (ARD)	Black stain root disease (BSRD)	Ganoderma root and butt rot	Heterobasidion root disease (HRD)	Laminated root rot (LRR)	Port-Orford-cedar root disease	Schweinitzii root and butt rot	Tomentosus root and butt rot	Yellow root rot
Spruces	Engelmann	2		3	3	2		2	1	3
	Sitka	2		3	3	3		2	2	3
True firs	Grand	1		3	1	1		3	3	3
	Noble	2		3	2	2		3	4	3
	Pacific silver	2		3	1	2		3	3	3
	Shasta red	2		3	2	2		3	4	3
	Subalpine	2		3	2	2		3	4	3
	White	1		3	1	1		3	3	3

1 = common, 2 = occasional, 3 = infrequent, 4 = rare, and blank means nonhost or unknown occurrence

Heart Rots

Heart rots are typically confined to the true heartwood of living trees, but some heart rot fungi can decay sapwood as well. The extent of decay is best correlated with tree age, not diameter. Most decay fungi gain access to living trees through branch stubs or wounds caused by humans, animals, fire, lightning, snow, high winds, bark beetles, or other agents. Wounds, callus tissue, conks, mushrooms, punk knots, swollen knots, old snow breaks, frost cracks, bole flattening, or depressions are all potential external indicators of internal decay. Additionally, signs of significant woodpecker activity, such as nest cavity excavation, often indicate the presence of advanced decay. Investigating inside wounds or drilling into the wood can confirm the presence and extent of this defect.

While external indicators may be visible, heart rot may also be present with few or no external indicators, especially in dry sites where conks are produced less frequently or when conks have fallen off the bole. A portion of the defect is typically hidden and inaccessible to the examiner by conventional means of visual evaluation (see the “Sound Rind Thickness and Determining the Extent of Decay” section in chapter 4). Heart rots in hardwoods commonly extend into the main branches resulting in weak branch unions that are prone to failure.

Assessing failure potential of trees with heart rot—Three heart rot species (quinine conks, rust-red stringy rot, and red ring rot) have specific rows in table 4.2 to help determine failure potential. For decays not specifically mentioned in table 4.2, use the first row of the “Conks” section of that table and tables 4.3 or 4.4 when conks are within drilling height. If drilling is not feasible due to the height of the conks, use the “other heart rot conks” row to determine failure potential of trees with heart rots. Extremely valuable trees may warrant climbing to drill and determine sound rind thickness at the height of the conk(s).

Aspen Trunk Rot

Causal agent—*Phellinus tremulae*

Hosts and distribution—Aspen throughout Oregon and Washington.

Identification—Conks are perennial, hard, woody, and generally hoof shaped (fig. A1.30). The undersurface is brown with small and regular pores. Early decay has a yellow-white zone in the heartwood and is usually surrounded by a yellow-green to brown margin. Advanced decay is soft and yellow white with fine, black zone lines.

Importance—A single conk generally indicates considerable internal decay. Sound rind thickness is best determined nearest the conk. Use the first row of the "Conks" section in table 4.2 if conks are within drilling height—or the "other heart rot conks" row if not—to determine failure potential.

Figure A1.30—*Phellinus tremulae* conk on aspen, an indicator of internal decay.

Brown Crumbly Rot

Causal agent—*Fomitopsis pinicola* species complex

Hosts and distribution—Most conifer tree species found throughout Oregon and Washington. This conk is commonly known as red belt fungus or red belt conk.

Identification—Conks are leathery to woody, perennial, and bracket shaped. When young, the conks appear white and round (fig. A1.31). As they mature, the upper surfaces turn dark gray to black, the lower pore surfaces remain white, and conspicuous reddish margins develop between the two surfaces—hence the common name "red belt conk" (fig. A1.32). Conks are very common on dead and downed trees and can be found associated with wounded live trees. Incipient decay is a faint yellow-brown to brown stain. Advanced decay is light reddish brown and forms a crumbly mass of rough, small cubes, which occasionally have mycelial felts between the shrinkage cracks. Mycelial felts are typically not as thick as those produced by *Laricifomes officinali*s, which causes brown trunk rot.

Importance—Red belt fungus is a primary decay organism of dead conifers in the Pacific Northwest. After tree or tissue death, decay develops rapidly in the sapwood and then progresses to the heartwood. Red belt can also cause heart rot of living trees, mostly commonly associated with bole wounds. It is important to determine sound rind thickness for live trees where conks are present or associated with wounds. For live trees, refer to the first row in the "Conks" section of table 4.2 if conks are within drilling height—or the "other heart rot conks" row if not—to determine failure potential. For dead trees with red belt conks, use the "dead tree" row in table 4.2.

Figure A1.31—Immature *Fomitopsis pinicola* conk emerging from a dwarf mistletoe stem canker on a western hemlock.

Figure A1.32—Typical "red belt" conks and associated decay from *Fomitopsis pinicola*.

Brown Cubical Rot

Causal agent—*Laetiporus conifericola* and *L. gilbertsonii* (both formerly *L. sulphureus*)

Hosts and distribution—*Laetiporus conifericola* infects most conifers; *L. gilbertsonii* infects many hardwoods. Both are widespread in Oregon and Washington.

Identification—The distinctive conks, known as the sulfur fungus or "chicken of the woods," are annual, orange yellow with multiple brackets, and usually occur on the butt and lower bole (fig. A1.33). Older, dead conks are chalky white and brittle and may persist for a year or two. Conks are commonly observed on dead trees or tree parts. Early decay is a light-brown stain. Advanced decay has red-brown cubes with white mycelial felts.

Importance—Decay is usually well advanced before conks develop. Use the first row of the "Conks" section in table 4.2 if conks are within drilling height—or the "other heart rot conks" row if not—to determine failure potential.

Figure A1.33—Conks of *Laetiporus conifericola* emerging from a snag with previous failure from brown cubical rot.

Brown Stringy Trunk Rot of Hardwoods

Causal agent—*Spongipellis delectans*

Hosts and distribution—Many hardwoods throughout Oregon and Washington.

Identification—Annual conks emerge from the butt or bole in varying shelflike shapes. The fleshy to leathery conks are white to cream with tawny-colored, rounded margins and small, uniform pores. Decaying wood is initially streaky brown and retains most of its structural strength. As decay advances, it turns a uniform brown, and the texture becomes stringy with occasional delamination of annual growth rings. Decay occurs in pockets mostly in the main stem; pockets coalesce as decay progresses. Decay continues after the host dies.

Importance—A single conk generally indicates considerable internal decay. Use the first row of the "Conks" section in table 4.2 if conks are within drilling height—or the "other heart rot conks" row if not—to determine failure potential.

Brown Top Rot

Causal agent—*Rhodofomes cajanderi* (formerly *Fomitopsis cajanderi*)

Hosts and distribution—Conifers throughout Oregon and Washington.

Identification—Perennial conks are woody and bracketlike to hoof shaped with a cracked brown to black upper surface and pink to rose-colored undersurface and inner tissue (fig. A1.34)—hence the common name "rose-colored conk." Conks are often stacked in a shelflike arrangement. Because conks are relatively small, those associated with broken tops may need to be viewed with binoculars. As such, conks are very difficult to detect, and even experienced evaluators easily overlook them.

The decay is a brown cubical heart rot. Early decay is a faint brownish or yellow-brown stain, sometimes marked by greenish-brown zone lines. Advanced decay is yellowish to reddish brown and soft with irregular cubes. White to faintly rose-colored thin mycelial felts may develop in the cracks of cubes.

Importance—Decay is usually found in trees with evidence of previous top damage. Conks commonly occur in the tops of trees with previous breakage but are difficult to see from the ground. Conks can also form on the lower bole where they are associated with codominant stems or bole wounds. Wood strength may be moderately affected before any discoloration or texture change becomes evident.

The amount of decay is proportional to the diameter of the broken stem, with decay progressing downward into the main stem and eventually upward into any new leaders that form after infection. Boles and new leaders on trees with one or more conks at the base of a new leader should be evaluated carefully; check sound rind thickness at conks where possible for a more accurate estimation of decay or examine conks using binoculars and refer to the "other heart rot conks" row in table 4.2 to determine whether any evidence of decay occurs around the conks.

Figure A1.34—Rose-colored conks of *Rhodofomes cajanderi*.

Brown Trunk Rot

Causal agent—*Laricifomes officinalis* (formerly *Fomitopsis officinalis*)

Hosts and distribution—Commonly found on old-growth Douglas-firs, pines, western larches, spruces, hemlocks, and occasionally true firs throughout Oregon and Washington. This fungus is commonly known as “quinine fungus” or “quinine conk.”

Identification—Conks are perennial, usually large, white, hoof shaped to pendulous with a chalky-white upper surface and a white or tan pore surface underneath (fig. A1.35). The conk’s interior is soft and crumbly. Conks develop at branch stubs, over old wounds, and often at the site of old broken tops. Punk knots may be observed at large, rotten branch stubs that have fallen off, often with yellowish brown stained bark below.

Figure A1.35—Characteristic large, white, pendulous *Laricifomes officinalis* conk.

Figure A1.36—*Laricifomes officinalis* conk and associated crumbly decay in a ponderosa pine.

The advanced decay is crumbly (fig. A1.36) with large, brown cubes that have thick mycelial felts in the shrinkage cracks. Felts can be ¼ in thick and can extend several feet in length as one continuous sheet with resinous pockets or crusts throughout.

Importance—The presence of even one conk generally indicates considerable internal decay. Severe stem decay may occur as a top rot when it has entered a broken top, or as a heart rot of the main stem when the infection site is lower in the bole, such as through a basal fire scar. Check sound rind thickness at the conk when possible for more accurate estimation of decay. Refer to the "quinine conks" row in table 4.4 to determine failure potential when trees cannot be drilled at the conk. Depending on target location and value, trees with quinine conks should always be considered for mitigation in any developed site.

Hardwood Trunk Rot

Causal agent—*Phellinus igniarius*

Hosts and distribution—Occurs on many hardwood species throughout Oregon and Washington.

Identification—Perennial conks are woody and generally hoof shaped with horizontal lower surfaces. The upper surface is gray black to black and rough when old. The undersurface is brown with small, regular pores. Early heartwood decay has a yellow-white zone and is usually surrounded by a yellow-green to brown margin. Advanced decay is soft and yellow white with fine black zone lines.

Importance—A single conk generally indicates considerable internal decay; use the first row of the "Conks" section in table 4.2 if conks are within drilling height—or the "other heart rot conks" row if not—to determine failure potential.

Incense Cedar Pecky Rot

Causal agent—*Oligoporus amarus*

Hosts and distribution—Incense cedars throughout Oregon and Washington.

Identification—Ephemeral, annual conks may be present at knots in late summer or autumn. Conks are hoof to half-bell shaped with tan to buff upper surfaces and bright sulfur-yellow undersides with small pores that exude drops of yellow liquid (fig. A1.37). Conks turn brown and hard with age. Depressions in the bark caused by woodpeckers searching for insects at former conk locations are good indicators of infection and decay. Large, open knots or open branch stubs indicate extensive decay. The advanced decay is a brown cubical decay similar to pencil rot of western redcedar.

Importance—Although tree failure is uncommon with pecky rot, failures can occur when this stem decay is associated with open wounds or bole cracks. This pocket rot of the heartwood is not limited to the butt and may occur along the entire bole. Decay is almost always present in older incense cedar (greater than 40-in diameter at breast height) with basal wounds or old dead limbs. Use the first row of the "Conks" section in table 4.2 if conks are within drilling height—or the "other heart rot conks" row if not—to determine failure potential.

Figure A1.37—Annual *Oligoporus amarus* conk on an incense cedar.

Inonotus Trunk Rots

Causal agent—*Inonotus dryophilus* and *Pseudoinonotus dryadeus* (syn. *I. dryadeus)*)

Hosts and distribution—Found primarily on hardwoods, especially oaks, and occasionally on conifers throughout Oregon and Washington.

Identification—*Pseudoinonotus dryadeus*, the weeping conk, produces large annual conks at the base of the tree near ground level or from roots. Conks have buff to brown upper and lower surfaces and exude amber-colored droplets when young. The conks become dark brown to black and cracked with age. *Inonotus dryophilus* produces corky annual conks with buff to reddish-brown upper and lower surfaces. The advanced decay is a white rot of the heartwood of living trees with conspicuous brown mycelia in the decayed wood.

Importance—These fungi cause a white rot of the heartwood in roots and butts of living trees. Trees with *P. dryadeus* conks often have substantial root decay. A single conk of either species generally indicates considerable internal decay; use the first row of the "Conks" section in table 4.2 if conks are within drilling height—or the "other heart rot conks" row if not—to determine failure potential.

Juniper Pocket Rot

Causal agent—*Pyrofomes demidoffii*

Hosts and distribution—Commonly found in older western junipers throughout Oregon and Washington.

Identification—Conks are perennial and hoof shaped with a brown to black upper surface and a buff to black rim. The undersurface is buff colored with round pores. Early decay is light yellow. Advanced decay is a white rot with abundant buff-colored mycelial felts in the decayed wood.

Importance—Trees with more than one conk have considerable decay but rarely fail; use the first row of the "Conks" section in table 4.2 if conks are within drilling height—or the "other heart rot conks" row if not—to determine failure potential.

Maple Trunk Rot

Causal agent—*Oxyporus populinus*

Hosts and distribution—Hardwoods, especially maples, in Oregon and Washington. This conk is commonly known and identified as the mossy-maple polypore.

Identification—Conks are perennial with multiple shelflike brackets occurring on the lower butt of decayed trees, typically near wounds, scars, or cracks. The upper surface is white to gray with a white margin and undersurface. Pores on the undersurface are very small. Older conks often have moss or liverworts growing on the upper surface. Decay is a white heart rot.

Importance—Conks generally indicate considerable internal decay; use the first row of the "Conks" section in table 4.2 if conks are within drilling height—or the "other heart rot conks" row if not—to determine failure potential.

Mottled Rot

Causal agent—*Pholiota adiposa* and *P. limonella*

Hosts and distribution—Many conifers and hardwoods of Oregon and Washington with significant decay occurring on true firs and hemlocks, especially in old-growth stands of true fir in eastern and southern Oregon. *Pholiota adiposa* is commonly referred to as "yellow cap fungus" and *P. limonella* as "lemon cap fungus."

Identification—Annual, gilled mushrooms are common on dead or old trees with areas of dead wood. Mushrooms are fleshy with yellow upper surfaces that are sticky when wet and have a yellow stipe (stalk) and yellowish to brown gills. Mushrooms develop individually or in close groups from a common base on host stems in the fall. Incipient heartwood decay is light yellow and is usually confined to small pockets. Decay pockets enlarge and coalesce with adjacent pockets, and as decay progresses the wood darkens to a honey color with brown streaks, which results in a mottled appearance. Decayed wood then becomes stringy after separating at the annual rings.

Importance—Failure potential of trees with one or more conks depends on the amount of sound rind thickness (use the first row in the "Conks" section of table 4.2). Trunks can become completely hollow. Most decay is in the lower bole but can extend 45–60 ft aboveground. If conks are above drilling height, use "other heart rot conks" row in table 4.2.

Redcedar Pencil Rot

Causal agent—*Postia sericeomollis*

Hosts and distribution—Western redcedars in Oregon and Washington.

Identification—Fruiting bodies occur as annual, thin white crusts but are uncommon and only indicate the presence of the fungus rather than providing an estimate of decay. Minor decay appears as long, thin columns ("pencils") of brown cubical decay (fig. A1.38), which become more abundant and begin to coalesce as decay becomes more extensive (fig. A1.39). In trees with large wounds or fire scars, large portions of the heartwood may be decayed.

Importance—Pencil rot is a severe stem decay and butt rot of western redcedars that is typically confined to the lower 40 ft of the bole. While no cull rules have been defined for this decay, bird cavities are a good indicator of advanced decay. Trees with significant decay may have conspicuous dead panels that result in bole flattening. The dead panels may be confused with irregularities in the butt associated with buttress roots or fluting. Failure potential of redcedars with pencil rot depends on the amount of sound rind thickness—refer to the "butt rot" row in table 4.2 and use table 4.4 for rind thickness thresholds in wounded trees.

Figure A1.38—Thin columns of limited decay in western redcedar caused by *Postia sericeomollis.*

Figure A1.39—Extensive decay in western redcedar caused by *Postia sericeomollis*.

Red Ring Rot or White Speck

Causal agent—*Porodaedalea pini* (formerly *Phellinus pini*)

Hosts and distribution—Most common stem decay of living conifers in Oregon and Washington, including Douglas-firs, western larches, pines, hemlocks, spruces, true firs, western redcedars, and rarely, incense cedars. Red ring rot is more severe in older stands, and in southern Oregon has been found more commonly in trees growing on steep slopes and shallow soils.

Identification—Hoof-shaped to bracketlike conks form at branch stubs or knots on the bole. Conks have a rough, dark-gray to brownish-black upper surface with concentric furrows. The undersurface is cinnamon brown to tan with pores that are irregularly shaped (fig. A1.40). The interior of the conk is cinnamon brown. Conks often have undulating margins. Punk knots often form at old branch stubs in severely decayed trees. True punk knots are filled with cinnamon-brown "punky" fungal material and may be clearly visible. Branch stubs, bark flaps, burls, and other features can look like conks or punk knots, and careful evaluation with binoculars is necessary to ensure the indicator is in fact a conk or punk knot. The decay caused by *P. pini* is a white pocket rot, a type of wood decay in which the lignin is decayed leaving small white pockets separated by sound wood (fig. A1.41).

Importance—Wood decayed by this pathogen maintains some strength against failure. Trees with conks should be evaluated carefully since failures are infrequent in resinous species. When Douglas-firs, pines, cedars, or larches have three or more large conks (≥8 in wide west of the Cascades or ≥6 in wide east of the Cascades) within a 3-ft trunk cylinder, heartwood decay may be extensive. Resinous tree species (table A2.1, appendix 2) with many small or few discrete large conks typically have incipient decay or small pockets of decay and are structurally sound. For nonresinous tree species, decay may be more extensive.

Refer to the "red ring rot" row in table 4.2 and sound rind thickness guidelines to determine failure potential. When drilling a tree with *P. pini* decay, consider firm (not crumbly) wood with white speck or red discoloration as having some residual wood strength.

Figure A1.40—*Porodaedalea pini* conk with a brownish-black, concentrically furrowed upper surface and tan lower surface.

Figure A1.41—Typical *Porodaedalea pini* advanced decay with small white pockets surrounded by sound wood.

Red Ring Rot Canker

Causal agent—*Porodaedalea cancriformans*

Hosts and distribution—Occurs on true firs, primarily in southwestern and west-central Oregon.

Identification—Conks are small and numerous with rough, dark, and furrowed upper surfaces (butterfly conks) and closely resemble *Porodaedalea pini* conks but are smaller and occur in clusters (fig. A1.42). The conks emerge from sunken areas on the bole above decayed wood.

Importance—Substantial amounts of stem breakage can occur with this fungus. Failure ratings should consider the percentage of defective cross-sectional wood and sound rind thickness at the canker (use the first row of the “Conks” section in table 4.2 if conks are within drilling height—or the “other heart rot conks” row if not—to determine failure potential).

Figure A1.42—A sunken canker with numerous, small *Porodaedalea cancriformans* conks.

Rust-Red Stringy Rot

Causal agent—*Echinodontium tinctorium*

Hosts and distribution—True firs and hemlocks in southern Oregon and east of the Cascade Crest in Oregon and Washington; especially damaging to older trees. This fungus is commonly known as Indian paint fungus or E.t.

Identification—Large, hoof-shaped conks with a spiny lower surface are relatively common on infected trees. Conks are woody with rough, dull black upper surfaces with fissures, while the undersurface is usually gray to black and level with hard, coarse teeth or spines (fig. A1.43). The conk interior and infected branch stub cores are rusty red to bright orange red. Conks often appear on the bole at the site of old branches. Advanced decay is a rust-red stringy rot that may result in nearly hollow stems (fig. A1.44).

Importance—The extent of decay from rust-red stringy rot depends on the number and size of conks and associated indications of extensive decay, such as cavities, exposed decay, or open structural cracks (table 4.2). Trees with a single conk can have up to 40 ft of continuous decay within the trunk. Multiple large conks indicate greater decay. Refer to the "rust-red stringy rot" row in table 4.2 and sound rind thickness guidelines to determine failure potential.

Figure A1.43—An *Echinodontium tinctorium* conk with toothed lower surface and rough, black upper surface.

Figure A1.44—Extensive rust-red stringy decay caused by *Echinodontium tinctorium*.

Sterile Conk Trunk Rot

Causal agent—*Inonotus obliquus*

Hosts and distribution—Alder, birch, and cottonwood species throughout Oregon and Washington.

Identification—Sterile conks are conspicuous, perennial, black masses of fungal tissue that erupt from stem cankers (fig. A1.45). The conk surface is rough and cracked; the interior is yellow brown to rust brown. Bole swelling is often present at the conk. Incipient decay is yellow white in irregular zones. Advanced decay appears as alternating zones of white and light reddish-brown wood. White veins of mycelium are common near cankers.

Importance—Trees with one or more conks should be checked for sound rind thickness at the conk(s) where possible; use the first row of the "Conks" section in table 4.2 if conks are within drilling height—or the "other heart rot conks" row if not—to determine failure potential.

Figure A1.45—A black mass of fungal tissue on a stem canker caused by *Inonotus obliquus*.

White Trunk Rot of Conifers

Causal agent—*Phellinus hartigii*

Hosts and distribution—Western hemlocks are the most commonly observed hosts, but it can also infect other conifers, especially true firs, throughout Oregon and Washington.

Identification—The conks are perennial and hoof shaped when on the bole. When formed on the lower surfaces of branches, the conks are flat against the branch and often occur where the branch joins the main stem, hence the common name "armpit fungus." In either case, the upper surface is dark brown to black, and the undersurface is brown and poroid (fig. A1.46).

The decay often occurs in sections of wood radiating in from the sapwood. Incipient decay is straw colored to purple and is irregular in shape. Advanced decay is bleached with occasional light-brown areas or streaks.

Importance—Trees with one or more conks should be checked for sound rind thickness at the conk(s) where possible (use the first row of the "Conks" section in table 4.2 if conks are within drilling height—or the "other heart rot conks" row if not—to determine failure potential). Trees with white trunk rot often fail within 20 ft of the ground.

Figure A1.46—*Phellinus hartigii* conk emerging below a branch on a western hemlock.

Yellow Pitted Rot

Causal agent—*Hericium abietis*

Hosts and distribution—True firs, hemlocks, and spruces throughout Oregon and Washington. Particularly common on the Olympic Peninsula and in the mountains of eastern Oregon and Washington. This fruiting body is commonly known as coral fungus or bear's head.

Identification—Distinctive, soft, creamy-white, corallike annual fruiting bodies occur at wounds on living trees in the fall (fig. A1.47). Incipient decay is a yellow to brown stain with scattered darker spots that create a mottled appearance. Advanced decay has elongated blunt-end pits, about ½ in long, which led to the old common name "long-pocket rot."

Importance— Trees with one or more fruiting bodies should be checked for sound rind thickness at the conk(s) where possible (use the first row of the "Conks" section in table 4.2 if conks are within drilling height—or the "other heart rot conks" row if not—to determine failure potential).

Figure A1.47—An annual fruiting body of *Hericium abietis*.

Sap Rots

Sap rots are decays that occur in the sapwood. Most sap-rotting fungi cause rapid decay only of dead sapwood. In most cases, decay by these fungi ceases once they have degraded all available dead sapwood, and no heartwood is decayed as they compete poorly with heartwood decay fungi. In living trees, sap rots occur on wood tissue damaged or killed by other agents, often from bark beetle strip attacks or localized damage caused by fire, mechanical wounds, or weather.

On dead trees, especially those killed by bark beetles, sap rot proceeds rapidly. On some true firs and hemlocks, sapwood is fully decayed within 1 to 2 years of tree death. On other conifers, it may take as many as 3 to 5 years for sap-rotting fungi to fully decay all available dead sapwood. Due to the high proportion of sapwood to heartwood, smaller trees and treetops typically fail sooner than larger trees due to sap-rotting fungi.

Hardwoods are also subject to sap-rotting fungi and damage may be significant on live trees. As with conifers, sap rotting of hardwoods occurs in dead portions of living trees. On many Pacific Northwest hardwood species (e.g., poplar, maple, alder), sapwood decays rapidly once the tree dies and there may be few obvious external indicators. When external indicators of sap rot are lacking, further examination may be required. Sap rot depth can be determined by using a drill, increment borer, or axe.

Assessing failure potential of trees with sap rot—Refer to the “sap rot conks” row in table 4.2 to determine failure potential of live trees with conks, always checking for other indicators of heartwood decay. Use the first row of the “Conks” section if a live tree has both conks and other wounds, and use the “dead trees” row if a tree with conks is dead.

Gray-Brown Sap Rot

Causal agent—*Cryptoporus volvatus*

Hosts and distribution—All conifers throughout Oregon and Washington. This fungus is commonly known as pouch fungus.

Identification—Conks are annual, leathery, and produced on trees the first 1 to 2 years following tree death. Fresh conks are small, round, initially soft and fleshy, yellow brown to golden brown with pore surfaces covered by a hard membrane; hence the common name "pouch fungus" (fig. A1.48). Conks bleach to a dirty white after 1 year. Early decay has gray areas that develop in the sapwood beneath the conks. Advanced decay appears the same, and white mycelial mats are present beneath the bark. Pouch fungus can completely decay sapwood.

Importance—The fungus is routinely introduced by bark beetles and wood borers and is very common on fire-killed and fire-damaged trees. Refer to the "sap rot conks" row in table 4.2 to determine failure potential of live trees with conks, always checking for other indicators of heartwood decay. Use the "dead trees" row for dead trees with conks, which are not considered a preexisting defect in dead trees.

Figure A1.48—*Cryptoporus volvatus* conks on a fire-damaged ponderosa pine indicate bark beetles and wood borers have infested the tree.

Pitted Sap Rot

Causal agent—*Trichaptum abietinum*

Hosts and distribution—All conifers and some hardwoods throughout Oregon and Washington. This fungus is commonly known as purple conk.

Identification—Conks are small, annual, thin, and shelflike. The upper surface is light gray, fuzzy, and zoned. Old conks become dark gray to black. The undersurface is violet to purple when fresh and turns light brown with age. As conks age, the angular pores become elongated and separate into spines or ridges. Incipient decay is light yellow to tan and soft; advanced decay has small pits that become elongated in the direction of the grain, with a honeycombed look.

Importance—The fungus infects its host via airborne spores through openings in the bark. Since this fungus is primarily a saprophyte, conks infrequently form on live trees but are numerous on dead trees and logs. Refer to the "sap rot conks" row in table 4.2 to determine failure potential of live trees with conks, always checking for other indicators of heartwood decay on live trees with conks. Use the "dead trees" row on dead trees with conks. If conks occur on live trees with wounds, use the first row of the "Conks" section in table 4.2.

Fungal Cankers and Stem Rusts

Fungal cankers and stem rusts are caused by fungi that infect and kill portions of tree boles and branches. Canker fungi cause topkill, branch death, and stem malformations that can be infected and subsequently decayed by other fungi, increasing the likelihood of stem breakage. Cankered areas on true firs, hemlocks, spruces, or hardwoods are more likely to be associated with failures than those on decay-resistant cedars or on resinous species, including Douglas-firs, pines, and larches, except for western gall rust on lodgepole pines. Failure potential does not significantly increase until the face of the canker is deeply sunken, or the cross section of the bole has a significant amount of deformed wood.

Assessing failure potential of trees with cankers—To assign failure potential for trees with cankers, use the "mistletoe cankers or fungal cankers" row in the "Bole" section of table 4.2 and check for evidence of decayed wood in and around the canker. If decay is observed, use the "bole wound" row and determine sound rind thickness.

Ceratocystis Canker

Causal agent—*Ceratocystis fimbriata*

Hosts and distribution—This disease, also commonly known as black canker, occurs on aspens and cottonwoods throughout Oregon and Washington.

Identification—Cankers are target shaped with or without bark adhering to the surface of the canker (fig. A1.49). The outside edges of cankers are often flared and may form a diamond or irregular shape due to the flaring. Old cankers are often blackened, elongated, and sunken as bark sloughs off canker centers over time. Infected wood behind the canker is usually stained. Microscopic fruiting bodies may be produced on the cankers but are difficult to detect.

Importance—Most cankers on aspen trees ultimately girdle the bole and kill the upper part of the tree. Over time, the depth of the canker increases and the structural strength of the bole at the infection decreases. The extent of deformed wood in the cross section of stem at the canker determines the failure potential. Additionally, associated decay resulting from infection by wood decay fungi at the canker may occur; in this case, use the "bole wound" row in table 4.2 to assess failure potential.

Figure A1.49—A target-shaped canker caused by *Ceratocystis fimbriata*.

Comandra Blister Rust

Causal agent—*Cronartium comandrae*

Hosts and distribution—Ponderosa pines and sometimes lodgepole pines; widely distributed throughout Oregon and Washington, but significant impacts occur at sporadic locations predominately east of the Cascade Crest in southern Washington and central Oregon.

Identification—Resin-soaked dead tops of larger ponderosa and lodgepole pines are an obvious indicator of this disease. On smaller trees, the disease results in elongated, diamond-shaped stem cankers and spindle-shaped swellings on small branches. Heavy resin flow from cankers is often associated with infection.

Importance—Mortality can occur, especially in young, infected trees. Large, infected pines exhibit dead tops that progressively die from the top down as the bole is slowly girdled (fig. A1.50). Infected and dead tops are relatively decay resistant because of the copious resin associated with infection. These dead tops have very low failure potential (refer to the "dead tops or branches" row in table 4.2), even after several decades, and rarely fail. Dead tops should still be examined for additional indicators of structural defects, such as cavities and open cracks.

Figure A1.50—*Cronartium comandrae* canker has caused topkill of this ponderosa pine.

Cryptosphaeria Canker

Causal agent—*Cryptosphaeria populina*

Hosts and distribution—Aspens and cottonwoods throughout Oregon and Washington.

Identification—Long, narrow cankers can extend for much of the length of the stem. Canker margins are light brown to orange. Small, highly visible, black fruiting bodies form in the bark. Dead bark adheres tightly to the canker. Diagnostic characteristics include sapwood staining and lens-shaped, convex, light-colored areas scattered throughout black, stringy, dead inner bark.

Importance—The pathogen colonizes the sapwood and heartwood causing stain and decay that may be extensive behind the canker. The extent of deformed wood or decay (refer to the "bole wound" row in table 4.2) determines failure potential.

Cytospora Canker

Causal agent—*Cytospora chrysosperma* and *C. abietis*

Hosts and distribution—*Cytospora chrysosperma* occurs on many hardwoods; *C. abietis* occurs primarily on true firs throughout Oregon and Washington.

Identification—Cankers occur on boles, branches, and twigs as elongated, sunken, dead areas with a slightly raised perimeter formed by annual callus growth. The inner bark of a canker turns brown to black, while the sapwood is light to reddish brown. Several years after infection, dead bark lifts away from the bole and readily falls off. Fruiting structures form beneath the cuticle of dead bark as disks that may exude long, orange-red, coiled tendrils of spores. Clusters of black fruiting bodies may also be present. On true firs, *C. abietis* commonly causes cankers associated with dwarf mistletoe infections, resulting in red-flagged branches throughout the crown.

Importance—Branch dieback, topkill, and mortality can occur. All dead trees and dead portions of living trees should be assessed for decay.

Hypoxylon Canker

Causal agent—*Entoleuca mammata* (formerly *Hypoxylon mammatum*)

Hosts and distribution—Hardwoods, including alders, cottonwoods, aspens, and willows, throughout Oregon and Washington.

Identification—Sunken, yellow-orange cankers are often centered around dead branch stubs or injuries. Older cankers have mottled bark with small, dead patches. Cankers can be up to 3 ft long, often girdling the stem. Fungal fruiting bodies form in gray to black stroma tissue that develops beneath dead bark on the surface of the canker. As the outer bark pushes away from underlying cortical tissues, the dark fungal fruiting bodies underneath are revealed.

Importance—Trees with hypoxylon canker may be girdled within 5 years. Most damage occurs on stressed or injured trees. Infected trees that are structurally weakened by *E. mammata* or associated decay fungi often fail at infection sites.

Madrone Canker

Causal agent—*Neofusicoccum arbuti* and *Fusicoccum aesculi*

Hosts and distribution—The Pacific madrone throughout its range in Oregon and Washington.

Identification—Cankers may girdle branches and stems causing branch flagging, topkill, or mortality. Infected branches turn purplish black, appear dry and cracked, and eventually die. Older stem cankers are sunken into the bark.

Importance—The causal fungus attacks weakened madrones, especially trees that are drought stressed, have mechanical wounds, or are suddenly exposed to full sunlight. Failures usually are infrequent until branches or stems have been dead for several years.

Mistletoe Cankers and Brooms

Causal agent—*Arceuthobium* spp. and *Phoradendron* spp.

Hosts and distribution—*Arceuthobium* spp. (dwarf mistletoes) occur on conifers while *Phoradendron* spp. (true mistletoes) occur on oaks, incense cedars, and western junipers. Both types of mistletoe are found throughout Oregon, and dwarf mistletoes are common across both Oregon and Washington.

Identification—Mistletoe plants often occur as conspicuous aerial shoots on infected branches and stems of host trees. Overall appearance of shoots (e.g., size, color) differs between *Phoradendron* spp. and *Arceuthobium* spp. as well as among individual species within each genus. Generally, *Arceuthobium* spp. may have small, scalelike leaves, and shoots may be yellow, purple, brown, or olive green. *Phoradendron* spp. have recognizable greenish leaves that can be scalelike or oval shaped on greenish shoots.

In all cases, mistletoe shoots are clustered and distinctive in appearance when compared to their host, and when shoots are not present, basal cups may be apparent on the bark of the infected area. Host response also varies across mistletoe-host combinations, but spindle-shaped branch swellings often form where an infection has occurred. Over time, host branches infected by dwarf mistletoes often develop brooms (i.e., abnormal, prolific branching) that are easy to detect (fig. A1.51). Bole infections often result in stem malformation in the form of swelling. Decay fungi

Figure A1.51—Large dwarf mistletoe brooms on a Douglas-fir.

can colonize these bole infections, and associated decay conks may be present. Decay associated with mistletoe bole infections is more common in hemlocks and true firs than in more resinous species.

Importance—Generally, *Phoradendron* spp. have negligible effects on their hosts, while most *Arceuthobium* spp. cause progressively more stress to their host as infection severity increases. Branch dieback and topkill can occur as infection severity increases for dwarf mistletoes, thus reducing host vigor. While branch infections are typical across all mistletoe-host combinations, bole infections are most common on grand and white firs, western hemlocks, and western larches. Both branch and bole infections result in structural changes of wood, but infection does not typically result in significant reductions of structural integrity. Instead, mistletoe infections create an entry point for decay fungi; as decay progresses over time, structural integrity is reduced, and the risk of failure increases.

Dead brooms (fig. A1.52) often fail with snow and ice loading. Therefore, these are especially of concern in areas that experience comparatively higher use in winter months (e.g., snow parks) than areas where visitor use is limited. To assess failure potential for trees with mistletoe bole infections, refer to the "mistletoe cankers or fungal cankers" row in table 4.2 , and for mistletoe brooms use the "dwarf mistletoe brooms" row. If decay is observed in and around the bole infection (common on true firs and western hemlocks), use the "bole wound" row and assess sound rind thickness.

Figure A1.52—Dead dwarf mistletoe brooms, especially large ones on Douglas-fir trees, are at risk of failure under snow and ice loading.

Nectria Canker

Causal agent—*Nectria cinnabarina*

Hosts and distribution—Hardwoods throughout Oregon and Washington.

Identification—Sunken cankers are associated with wounds or develop at the base of dying branches. Cankers can girdle and kill stems, and when bark dies it appears dry and cracked with age. Conspicuous orange to pink erumpent fruiting bodies are typically present along dead sections of infected branches.

Importance—*Nectria cinnabarina* is a weak, opportunistic pathogen of stressed or wounded trees. Cankers expand when the host is dormant and can girdle stems causing branch dieback. While *N. cinnabarina* does not cause decay, decay fungi often colonize dead branches, which may result in branch failures.

Ramorum Canker and Sudden Oak Death

Causal agent—*Phytophthora ramorum*

Hosts and distribution—This canker is primarily found on tanoak in southwestern Oregon.

Identification—All sizes and ages of tanoaks (seedlings, saplings, mature trees) can be infected and killed. Rapid mortality can occur with a sudden browning of leaves throughout the entire crown, but progressive crown symptoms may also occur. Cankers appear as red brown to black areas of bark that often seep dark-black to red or amber sap.

Importance—*Phytophthora ramorum* is a nonnative, funguslike water mold that was introduced into southern Oregon around 2000. This pathogen is the cause of sudden oak death, and ramorum canker is mentioned in the context of hazard trees because of the relatively rapid death of its principal host in Oregon, tanoak. Infected trees are rapidly colonized by decay fungi, and trunk failures can occur even before trees are completely dead. If you suspect *P. ramorum*, consider the tree(s) to have a very high failure potential and contact your area pathologist(s) for further assistance on proper sanitation techniques for infested material.

Sooty-Bark Canker

Causal agent—*Encoelia pruinosa*

Hosts and distribution—Aspens and cottonwoods throughout Oregon and Washington.

Identification—Sooty-bark cankers often have arcs of blackened bark tissue resulting in a "barber pole" appearance. Small silver-gray, cuplike fruiting bodies of *E. pruinosa* can be found on older cankered bark.

Importance—Sooty-bark canker often results in tree mortality. As with other canker diseases, the percentage of defective, cross-sectional wood should be estimated at the canker. Wood decay fungi may also be present, and sound rind thickness should be estimated where decay is evident.

Western Gall Rust

Causal agent—*Endocronartium harknessii*

Hosts and distribution—Very common on lodgepole and ponderosa pines throughout Oregon and Washington. May be locally important on knobcone and knobcone-Monterey hybrid pines, especially near waterways.

Identification—The galls are small and round or pear shaped when found on branches or small trees. On the main stems of large trees, “hip cankers” can be the width of the host tree and are caused when the main stem flattens and broadens as it grows around bole infections (fig. A1.53). Bright yellow-orange spore pustules are produced in cracks of galls in late spring and early summer.

Importance—The disease causes branch flagging, bole breakage, topkill, and mortality of young trees. Galls on the main stem, or “hip cankers,” develop progressively and increase the tree’s failure potential as the percentage of sound wood in the bole decreases. Stem breakage in lodgepole pine tends to occur directly above the canker and often occurs during winter storm events. Failure potential depends on the percentage of the stem’s cross section with deformed wood at the canker (use the “western gall rust canker” row in table 4.2 to assign failure potential).

Figure A1.53—An *Endocronartium harknessii* “hip canker” causing stem deformation.

White Pine Blister Rust

Causal agent—*Cronartium ribicola*

Hosts and distribution—Five-needle pines (sugar, western white, and whitebark) throughout Oregon and Washington.

Identification—*Cronartium ribicola* infects its host through needle stomates. As the infection progresses into the branch, spindle-shaped swellings are formed. Bright yellow-orange pustules are produced and erupt through the bark associated with a canker. Cankers result in dead, roughened bark with margins that appear orangish. Heavy pitch flow often occurs with bole cankers, and associated insect damage and rodent feeding are both common.

Importance—White pine blister rust is caused by the nonnative fungus *C. ribicola* and is the most significant disease of five-needle pines. Cankers resulting from *C. ribicola* infection may cause branch flagging, topkill, and mortality (fig. A1.54). Infected and dead tops are relatively decay resistant because of the copious resin associated with infection. Rust-killed tops have very low failure potential even after several years and rarely fail.

Figure A1.54—A white pine blister rust canker causing topkill on a western white pine.

Other Defects

Insect-Caused Damages

Forest insects can weaken roots, stems, tops, or branches through physical degradation of wood and by introducing fungi that result in wood decay. The insects of primary concern in hazard tree management are bark beetles, wood borers, carpenter ants, and termites.

Bark beetles cause tree mortality across the world, including in the Pacific Northwest. The most important beetles in this region are the Douglas-fir beetle, fir engraver, spruce beetle, mountain pine beetle, western pine beetle, and pine engraver. Bark beetles frequently attack trees that are stressed from root disease, bole damage, defoliation, or drought. Symptoms and signs of bark beetle attack include pitch tubes (fig. A1.55), boring dust, galleries under the bark, fading or red crowns, dead tops, and group mortality

Trees successfully mass-attacked by bark beetles, such as the mountain pine beetle and western pine beetle, may have boring dust or cream-colored to reddish pitch tubes along their bole, even if crowns are still green the year of attack. Douglas-firs and true firs attacked by bark beetles do not exhibit the same pitch tubes as pine bark beetles; however, clear resin "pitch streamers" may exude from attacks high on the stem. Pitch streamers on Douglas-firs often occur for other reasons, such as mechanical or fire damage, and should not be solely used to identify trees attacked by beetles. Better indicators are the abundant, reddish frass piles within bark crevices that are found the year of attack.

Trees mass-attacked by bark beetles are likely to die within 1 year. Further information on individual bark beetles in the Pacific Northwest can be found in Goheen and Willhite (2021). Trees killed by bark beetles are assessed for failure potential using table 4.5 or the "dead tree" row in tables 4.1 or 4.2.

Wood borers generally prefer weak hosts, readily colonizing recently killed or very stressed trees, although some borers can cause mortality. Wood borers can significantly lower the structural integrity of infested trees because they commonly bore through the sapwood into the heartwood. In southwestern Oregon, the flatheaded fir borer actively kills low-elevation, stressed Douglas-firs.

Wood borers and bark beetles almost always carry spores of staining and decay fungi into infested trees. Trees with wood borer holes in exposed wood need to be closely examined. Ambrosia beetles will colonize recently killed trees or portions of recently killed trees. They are often found at the base of true firs and hemlocks and indicate at least a portion of the circumference of the tree is dead. Unlike the frass from bark beetles, the frass from Ambrosia beetles is white.

Carpenter ants and termites colonize trees with dead or decayed wood, further weakening them (fig. A1.56). Trees with very thick bark can have carpenter ant activity that is restricted to the bark with no degradation of wood. As a result, evidence of carpenter ants should be carefully evaluated. When carpenter ants and termites are in the wood of live trees, refer to the “bole wounds” row in table 4.2 and sound rind thickness thresholds (tables 4.3 or 4.4).

Figure A1.55—Pitch tubes on a lodgepole pine from mountain pine beetle attack.

Figure A1.56—Large piles of insect boring dust often indicate the presence of carpenter ants or termites and require further investigation.

Burls

Burls are abnormal swellings on stems and branches (fig. A1.57). Usually, burls are composed of undecayed wood and, as such, trees with burls have very low failure potential. Burls vary in size but can be several feet in diameter. Their cause is mostly unknown, but they are common among high-elevation tree species, such as lodgepole pine and subalpine fir. When high in the tree, or covered with moss or lichens, burls sometimes resemble conks and therefore require careful examination with binoculars.

Figure A1.57—Conspicuous, large burls on a spruce.

Sapsucker Damage

Sapsuckers are a type of woodpecker that drill small, round holes into trees, typically in straight horizontal or vertical rows. They feed on the sap and associated insects that are attracted to the sap. Sapsucker damage to trees, while noticeable, is mostly superficial and rarely causes a defect to the tree or a loss of structural integrity (fig. A1.51). Woodpecker activity for nest sites should not be confused with superficial sapsucker damage.

Figure A1.51—Typical pattern of sapsucker activity (horizonal lines of holes) that is not an indicator of advanced decay.

APPENDIX 2

Profiles of Common Tree Species and Groups in Oregon and Washington Forests

Species profiles are not well developed for hazard tree evaluations. This appendix represents a compilation of available literature from Dunster (2003), Burns and Honkala (1990), Filip et al. (2013), Goheen and Willhite (2021), and the accumulated experience of Forest Service pathologists in the Pacific Northwest.

Table A2.1—Resinous and nonresinous tree species groups in Oregon and Washington forests

Tree species group	Resinous or decay resistant
Cedars	Nonresinous but decay resistant
Douglas-firs	Yes
Hemlocks	No
Larches	Yes
Pines	Yes
Spruces	Partially
True firs	No
Hardwoods	Nonresinous, some more decay resistant than others

Recreation site records covering a 10-year period in the Pacific Northwest illustrate the frequency of tree failure by position of the defect on the tree and by tree species (table A2.2). In general, trees failed across all defect positions, but root or butt (i.e. lower base of bole) defects accounted for nearly two-thirds of all recorded failures. Upper and lower bole failures accounted for approximately one-third of failures. For some tree species, failures were common in the upper bole, including true firs such as noble and subalpine firs, some hardwoods, and ponderosa pines. Limb failures occurred infrequently and were more common in hardwoods than in conifers.

Table A2.2—Distribution of failures by position of defect and tree species in Pacific Northwest recreation sites

Tree Species	Upper bole (%)	Lower bole (%)	Butt (%)	Branch (%)	Root (%)	Total number
Alder	23	11	30	1	35	154
Douglas-fir	17	11	15	3	54	404
Engelmann spruce	0	3	34	0	63	38
Grand fir	12	18	18	0	53	34
Incense-cedar	14	29	8	4	44	111
Larch	8	26	4	4	58	26
Lodgepole pine	13	8	7	3	69	637
Madrone	10	2	28	42	18	321
Maple	13	4	30	9	47	47
Mountain hemlock	12	77	0	0	12	43
Noble fir	37	11	0	0	53	19
Pacific silver fir	5	48	5	0	43	21
Ponderosa pine	42	6	5	0	47	280
Poplar	15	12	19	31	23	26
Red fir	16	30	13	1	40	87
Sitka spruce	18	27	18	0	36	11
Spruce, unidentified	0	53	0	0	47	297
Subalpine fir	55	3	24	0	17	29
Sugar pine	14	25	17	8	36	36
Tanoak	13	24	18	16	28	1,614
Western hemlock	4	18	19	1	58	113
Western redcedar	0	15	12	10	63	41
White fir	6	53	15	0	26	34
Average/Total	15	22	15	6	42	4,423

Source: Harvey and Hessburg (1992)

Conifers

Cedars

Distribution and Habitat

- Alaska yellow-cedar (*Cupressus nootkatensis*)—Found in isolated locations within Oregon and Washington, particularly in the Cascade Range and Olympic Mountains at elevations above 2,000 feet where the climate remains cool and humid
- Incense cedar (*Calocedrus decurrens*)—In Oregon, found exclusively on montane sites with dry summer conditions. Does not occur naturally in Washinton.
- Port-Orford-cedar (*Chamaecyparis lawsoniana*)—Has a limited range and occurs naturally only in southwestern Oregon near the Pacific coast.
- Western redcedar (*Thuja plicata*)—Common in moist sites along streams and other wet areas in both Oregon and Washington.

Common defects—Though not resinous and with relatively thin bark, the wood has decay-resistant properties. Western redcedar's preference for moist areas can result in limited rooting depth. Western redcedars often have a fluted base due to the presence of buttress roots that provide structural stability, which can complicate utilization of sound rind thickness guidelines to make failure potential determinations.

General failure potential—Wood is generally decay resistant. Where stem decay does occur, it is typically present in pockets. However, extensive heartwood decay is common in live western redcedar, often associated with basal wounds or fire scars. Failure of forks, related to heartwood decay, is common. Spike tops are relatively common, especially after droughts, and can persist for decades with minimal risk of failure.

Common Diseases Influencing Failure Potential

- Cedar laminated root rot (*Coniferiporia weirii*), page 125
- Incense cedar pecky rot (*Oligoporus amarus*), page 149
- Redcedar pencil rot (*Postia sericeomollis*), page 152

Douglas-firs

Distribution and habitat—Douglas-firs grow in forests throughout Oregon and Washington. There are two varieties: coastal Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) and interior or Rocky Mountain Douglas-fir (*P. menziesii* var. *glauca*), which differ somewhat in their susceptibility to pathogens. Coastal Douglas-firs commonly live past 500 years and can reach 1,500 years old, while the interior variety typically survives less than 400 years.

Common defects—Windthrow on shallow, wet, or rocky soils can occur, though the species is deep rooted in rich, well-drained soils. Root diseases are prevalent and frequently lead to whole tree failure. Douglas-fir dwarf mistletoe infections, more commonly found east of the Cascade Crest and in southwestern Oregon, often result in large brooms that may become brittle and break after branch death or under snow and ice loading. Severe Douglas-fir dwarf mistletoe infections often result in dead tops. Failure of large, lateral limbs is common in windy conditions.

General failure potential—Whole tree failure due to root disease or root and butt decay is the most often observed failure. Trees of all ages are commonly infected with laminated root rot. Schweinitzii root and butt rot frequently leads to failures at the butt and roots in mature trees and is a primary cause of mortality in Douglas-firs more than 300 years old. As a resinous species with relatively thick bark, Douglas-firs are less susceptible to wounding and subsequent decay than many other conifers.

Common Diseases Influencing Failure Potential

- Armillaria root disease (*Armillaria* spp.), page 117
- Brown top rot (*Rhodofomes cajanderi*), page 145
- Brown trunk rot (quinine fungus) (*Laricifomes officinalis*), page 146
- Laminated root rot (*Coniferiporia sulphurascens*), page 125
- Red ring rot (*Porodaedalea pini*), page 153
- Schweinitzii root and butt rot (*Phaeolus schweinitzii*), page 130

Hemlocks

Distribution and Habitat

- Mountain hemlock (*Tsuga mertensiana*)—Found throughout the Pacific Northwest at higher elevations in cold, snowy, subalpine locations.
- Western hemlock (T*suga heterophylla*)—Found throughout Oregon and Washington, flourishing on moist sites.

Common defects—Both species frequently develop significant heart rot, particularly in older trees. Internal wood decay in the western hemlock is often associated with bole wounds and top breakage. Hemlocks have relatively thin bark and are prone to wounding and frost cracks. Wood decay in hemlocks associated with bole wounds can progress more rapidly compared to more resinous species, shortening the time between infection and tree failure. Both the heartwood and sapwood are prone to decay resulting in snags that are short lived.

Mountain hemlocks are more susceptible to laminated root rot than western hemlocks, although damage to western hemlocks can be locally severe. Both species are highly susceptible to Heterobasidion root disease, which often acts as a butt or stem decay. Dwarf mistletoe infections are locally important and can provide entry points for decay fungi.

General failure potential—Stem breakage and windthrow are the most common forms of failure in both western and mountain hemlocks. The western hemlock is shallow rooted, regardless of soil conditions, and does not develop a taproot, which contributes to increased likelihood of windthrow. Hemlocks are also susceptible to multiple root diseases, but external indicators are not always evident. Trees with apparently healthy crowns can have advanced, internal stem decay. Conks or fungal fruiting bodies, exposed wounds, broken tops, and cracks can be reliable indicators of wood decay.

Common Diseases Influencing Failure Potential

- Armillaria root disease (*Armillaria* spp.), page 117
- Brown trunk rot (quinine fungus) (*Laricifomes officinalis*), page 146
- Ganoderma root, butt, and trunk rots (*Ganoderma* spp.), page 121
- Heterobasidion root disease and stem decay (*Heterobasidion occidentale*), page 122
- Laminated root rot (*Coniferiporia sulphurascens*), page 125
- Inonotus trunk rots (*Inonotus dryophilus* and *Pseudoinonotus dryadeus*), page 150
- Red ring rot (*Porodaedalea pini*), page 153
- Rust-red stringy rot (*Echinodontium tinctorium*), page 156
- White trunk rot (*Phellinus hartigii*), page 158
- Yellow pitted rot (*Hericium abietis*), page 159

Larches

Distribution and Habitat

- Alpine larch (*Larix lyallii*)—Found near the timberline in the Cascade Range of Washington.
- Western larch (*Larix occidentalis*)—Found primarily east of the Cascade Crest on relatively cool, moist sites.

Common defects—The western larch develops a deep and extensive root system. As a result, larches are resistant to windthrow, and where windthrow does occur, it is usually related to root and butt decay. Mature larch trees have very thick bark, which provides some resistance to fire and wounding.

General failure potential—Dwarf mistletoe infections are very common. While the brooms themselves tend to be small, the wood becomes very brittle and infested branches commonly fail under snow or ice load. Severe dwarf mistletoe infections frequently result in dead tops and create entry points for decay fungi. Laminated root rot and schweinitzii root and butt rot can be locally significant and result in whole tree failures.

Common Diseases Influencing Failure Potential

- Brown trunk rot (quinine fungus) (*Laricifomes officinalis*), page 146
- Laminated root rot (*Coniferiporia sulphurascens*), page 125
- Red ring rot (*Porodaedalea pini*), page 153
- Schweinitzii root and butt rot (*Phaeolus schweinitzii*), page 130

Pines

Profiles include two- and three-needle pines (lodgepole and ponderosa) and five-needle pines (western white, sugar, and whitebark).

Distribution and Habitat

- Three varieties of lodgepole pines in Oregon and Washington include:
    - A coastal variety known as shore pine (Pinus contorta var. contorta).
    - Two inland varieties referred to as Rocky Mountain lodgepole (P. contorta var. latifolia) and Sierra lodgepole (P. contorta var. murrayana), which grow across an array of habitats.
- Ponderosa pine (*Pinus ponderosa*)—Widely distributed, primarily on drier sites, and common east of the Cascade Crest, in southwestern Oregon, and lower elevations in the Willamette Valley.
- Sugar pine (*Pinus lambertiana*)—Primarily found in the Siskiyou and Klamath Mountains of southern Oregon and at mid-elevation sites throughout central Oregon. It also extends north along the western slopes of the Cascade Mountains in Oregon.
- Western white pine (*Pinus monticola*)—Widely distributed across Oregon and Washington; prefers deep, porous soils on montane sites.
- Whitebark pine (*Pinus albicaulis*)—Occurs in both Oregon and Washington in high-elevation forests at or near the timberline.

Common defects—Forked tops are common in ponderosa and lodgepole pines. Western gall rust can be locally prevalent and damaging in lodgepole and ponderosa pines. Dead tops caused by comandra and white pine blister rusts are often permeated with resin and have low failure potential.

General failure potential—Pines are resinous species that can seal fresh wounds with pitch, which can limit establishment of decay fungi. Western gall rust cankers on lodgepole and ponderosa pines are often points of stem failure as the cankers progress and decrease the proportion of sound wood. Top breakage at forks is common. Advanced heartwood decay in mature trees is a primary cause of stem failure.

Common Diseases Influencing Failure Potential

- Armillaria root disease (*Armillaria* spp.), page 117
- Brown trunk rot (quinine fungus) (*Laricifomes officinalis*), page 146
- Heterobasidion root disease (*Heterobasidion irregulare*), page 122
- Red ring rot (*Porodaedalea pini*), page 153
- Schweinitzii root and butt rot (*Phaeolus schweinitzii*), page 130
- Western gall rust (*Endocronartium harknessii*), page 171

Spruces

Distribution and Habitat

- Engelmann spruce (*Picea engelmannii*)—In both Oregon and Washington, this species occupies cold sites at higher elevations and in cool air drainages.
- Sitka spruce (*Picea sitchensis*)—A Pacific maritime species found primarily within 20 miles of the coast on moist, well-drained sites.

Common defects—Spruce trees have strong wood, especially the Sitka spruce, that is not decay resistant. Relatively thin bark increases susceptibility to wounding. Bole wounds and top breakage are frequently associated with stem decay.

General failure potential—Whole tree failures in mature (more than 250 years old) Sitka spruce are often due to schweinitzii root and butt rot. In the Engelmann spruce, tomentosus root and butt rot is the most common cause of tree failure, though other decay fungi can also contribute to root and butt rot in this species. Stem breakage and uprooting forms of failure are common, especially in trees with previously broken tops and wounds where decay fungi have been active. Basal wounds in live trees can be associated with internal decay caused by the red belt fungus and lead to whole tree failure.

Common Diseases Influencing Failure Potential

- Armillaria root disease (*Armillaria* spp.), page 117
- Brown crumbly rot (*Fomitopsis pinicola* species complex), page 142
- Laminated root rot (C*oniferiporia sulphurascens*), page 125
- Red ring rot (*Porodaedalea pini*), page 153
- Schweinitzii root and butt rot (*Phaeolus schweinitzii*), page 130
- Tomentosus root and butt rot (*Onnia tomentosa*), page 133

True firs

Distribution and habitat—True firs are found throughout Oregon and Washington. The species have distinct ranges but often co-occur.

- Grand fir (*Abies grandis*)—Prefers cool, moist sites along stream bottoms, valleys, and mountain slopes up to around 5,000 feet in elevation.
- Noble fir (*Abies procera*)—Found in moist regions of the Cascade Range in Oregon and Washington and localized populations on peaks in the Coast Range.
- Pacific silver fir (*Abies amabilis*)—Commonly found in the Olympic Mountains and Coast Ranges of Washington and along the western slopes and upper eastern slopes of the Cascade Range in Oregon and Washington.
- Shasta red fir (*Abies magnifica* var. *shastensis*)—Occurs in southern Oregon in a cooler high-elevation band, but tolerates the dry summers of southwest Oregon.
- Subalpine fir (*Abies lasiocarpa*)—Found primarily on high-elevation sites.
- White fir (*Abies concolor*)—Found on middle to upper elevation sites in south-central Oregon and in the Coast and Cascade Ranges.

Common defects—True firs are generally decay-prone, short-lived species. They typically have thin bark, especially when young, which leads to high susceptibility to wounds and frost cracks and subsequent wood decay. Dwarf mistletoe infections are locally important and provide entry points for decay and canker fungi, and severe dwarf mistletoe infections result in dead tops. In areas where soil conditions limit rooting depth, true firs are susceptible to windthrow.

General failure potential—Wounds are common, and root diseases and stem decays frequently lead to tree failure. Grand and white firs are highly susceptible to the three major root diseases in the Pacific Northwest (Armillaria root disease, Heterobasidion root disease, and laminated root rot). Root grafting is commonplace and promotes the spread of root pathogens. The wood of true firs is soft, weak, and prone to decay.

Common Diseases Influencing Failure Potential

- Armillaria root disease (*Armillaria* spp.), page 117
- Heterobasidion root disease and stem decay (*Heterobasidion occidentale*), page 122
- Laminated root rot (*Coniferiporia sulphurascens*), page 125
- Mottled rot (*Pholiota* spp.), page 151
- Red ring rot (*Porodaedalea pini*), page 153
- Red ring rot canker (*Porodaedalea cancriformans*), page 155
- Rust-red stringy rot (*Echinodontium tinctorium*), page 156

- Tomentosus root and butt rot (*Onnia tomentosa*), page 133
- Yellow pitted rot (*Hericium abietis*), page 159

Hardwoods

Alders

Distribution and habitat—The red alder (*Alnus rubra*) is a fast-growing, short-lived deciduous species found primarily west of the Cascades and in the Coast Range. Red alders often occupy areas after disturbance and commonly occur along roadsides. Other alders (*Alnus* spp.) occur throughout Oregon and Washington, primarily in riparian areas. Alders grow on a variety of soils and can tolerate sites with poor drainage and occasional flooding.

Common defects—Red alders are thin barked and easily wounded. Damage from wind, ice, and heavy snow can lead to upper crown or stem failure. Sunscald can be extensive and serve as an entry point for decay fungi. Alders are generally windfirm despite their regular leaning habit. Cankers are locally significant on some alders in riparian areas.

General failure potential—Red alders have thin bark and wood that is moderately strong but not decay resistant. Wounded trees, regardless of age, may have extensive decay resulting in tree failure. Mature trees may have crown dieback and readily shed large limbs. Stem breakage can occur at cankers and in dead tops. Undermined roots may be common in riparian areas.

Common Diseases Influencing Failure Potential

- Brown stringy trunk rot of hardwoods (*Spongipellis delectans*), page 144

Aspen

Distribution and habitat—Quaking aspens (*Populus tremuloides*) occur primarily along the Cascade Range and in portions of eastern Oregon and Washington, but the species also occurs at some locations west of the Cascade Range. After disturbance, the aspen is a pioneer species and often grows on moist sites across a range of elevations and soil types.

Common defects—Aspens possess light, soft wood, and trees are prone to branch, stem, and root decay. Dead branches are common entry points for canker and decay fungi. Aspens have thin bark, which makes it susceptible to wounding from various causes and subsequent wood decay. Dead tops are often present in aspen stands of appreciable age.

General failure potential—The aspen is a relatively fast-growing, short-lived species. Wounds are common, and stem decays are a frequent cause of tree failure. Stem cankers are common, often associated with extensive stem decay, and frequently kill trees.

Common Diseases Influencing Failure Potential

- Armillaria root disease (*Armillaria* spp.), page 117
- Aspen trunk rot (*Phellinus tremulae*), page 141
- Ceratocystis canker (*Ceratocystis fimbriata*), page 163
- Cryptosphaeria canker (*Cryptosphaeria populina*), page 165
- Hypoxylon canker (*Entoleuca mammata*), page 166
- Inonotus trunk rots (*Inonotus dryophilus* and *Pseudoinonotus dryadeus*), page 150
- Nectria canker (*Nectria cinnabarina*), page 169
- Sooty-bark canker (*Encoelia pruinosa*), page 170

Bigleaf Maple

Distribution and habitat—The bigleaf maple (*Acer macrophyllum*) is native to a belt extending from the western slopes of the Cascade Range to the Pacific coast, where it thrives in diverse habitats, from flat and gently sloping interior valleys and stream bottoms to moderate to steep slopes and rocky ridges. On poorly drained soils, the root system is usually shallow and extensive, but on better drained soils, the root system tends to be deeper.

Common defects—Bigleaf maples often have shallow roots and surface roots that are easily damaged, providing entry points for decay fungi. Trees form large scaffold branches that are susceptible to decay on their upper and inner surfaces.

General failure potential—Failures are most common in decadent trees. Root, butt, and stem decays are often present in older trees but typically produce obvious signs, such as conks. Failures related to poor tree architecture are common. Large scaffold branches may be decayed. These branches can also support large populations of epiphytic plants whose weight can be heavy enough to initiate branch failure.

Common Diseases Influencing Failure Potential

- Armillaria root disease (*Armillaria* spp.), page 117
- Brown cubical rot (*Laetiporus gilbertsonii*), page 143
- Brown stringy trunk rot of hardwoods (*Spongipellis delectans*), page 144
- Ganoderma root and butt rot (*Ganoderma applanatum*), page 121
- Inonotus trunk rots (*Inonotus dryophilus* and *Pseudoinonotus dryadeus*), page 150
- Maple trunk rot (*Oxyporus populinus*), page 151

Black Cottonwood

Distribution and habitat—Black cottonwoods (*Populus balsamifera* ssp. *trichocarpa*, *Populus trichocarpa*) are typically found on moist sites throughout Oregon and Washington. Considered shade and drought intolerant, black cottonwoods develop deep and extensive root systems where soils allow. In wet areas with high water tables, roots are very shallow.

Common defects—Cottonwoods are fast-growing, short-lived trees with weak wood. Trees form large scaffold branches that are prone to breakage. Codominant stems are common, and those with embedded bark often have weak stem unions.

General failure potential—Branch failure is common, and although most failures are wind related, they can occur under apparently windless conditions (referred to as "sudden limb drop"). Branch breakage provides entry courts for decay fungi, which often leads to additional branch breakage. Stem failures in mature trees are usually related to extensive decay. Windthrow is common where trees are shallowly rooted.

Common Diseases Influencing Failure Potential

- Armillaria root disease (*Armillaria* spp.), page 117
- Brown stringy trunk rot of hardwoods (*Spongipellis delectans*), page 144
- Inonotus trunk rots (*Inonotus dryophilus* and P*seudoinonotus dryadeus*), page 150

Oregon White Oak

Distribution and habitat—Oregon white oak (*Quercus garryana*), also called Garry oak, is found primarily west of the Cascade Range and east of the Coast Range in Oregon and Washington, though it extends east of the Cascades along and near the Columbia River. In Oregon, it is common in lower elevation valleys including the Willamette, Umpqua, and Rogue River valleys. It is most common on harsh sites that are too dry or exposed to support other species. Oregon white oak can also be found on very moist sites, such as flood plains, where it can survive both long periods of flooding and drought.

Common defects—Bole wounds are frequently encountered.

General failure potential—Oregon white oak forms a deep taproot and extensive lateral roots and is typically very windfirm. The species is long lived and produces strong wood. It is not adapted to irrigated landscapes, and failures in these areas due to root diseases are common. Wounds and cankers related to mistletoe infections can serve as entry points for branch and stem decay fungi.

Common Diseases Influencing Failure Potential

- Armillaria root disease (*Armillaria* spp.), page 117
- Brown cubical rot (*Laetiporus gilbertsonii*), page 143
- Brown stringy trunk rot of hardwoods (*Spongipellis delectans*), page 144
- Inonotus trunk rots (*Inonotus dryophilus* and *Pseudoinonotus dryadeus*), page 150

Pacific Madrone

Distribution and habitat—The pacific madrone (*Arbutus menziesii*) is a broadleaved evergreen hardwood found primarily west of the Cascades and in the Coast Range. Madrones often grow with Douglas-firs, ponderosa pines, and Oregon white oaks. It is easily recognized by its reddish-orange, smooth, and peeling bark.

Common defects—Madrones are thin barked and easily wounded. Sunscald is a common defect along roads and in developed areas and can serve as an entry point for decay fungi. Decay and cankers often develop associated with wounds and lead to dead branches, stems, and tops.

General failure potential—Madrones are very sensitive to disturbance and compaction around the root collar, including alteration of the grade or drainage around the tree. This often leads to decline and possible mortality from Phytophthora root and collar rot. Madrone canker is a common disease identified by the blackened or charred appearance of impacted parts. Madrone canker often leads to stem death and breakage and occasionally whole tree mortality. Wounded trees often will have decay caused by madrone canker resulting in crown dieback, limb failure, or both. Stem breakage can occur at cankers and in dead tops.

Common Diseases Influencing Failure Potential

- Madrone canker (*Neofusiococcum arbuti*), page 166

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GLOSSARY

Glossary

Advanced decay—later stages of decay often characterized by crumbling or stringy wood structure

Aeciospore—type of spore produced in an aecium that typically infects alternate hosts

Bark beetles—a group of often destructive forest insects whose adults and larvae make galleries in the phloem and cambial regions of living or felled trees; a subfamily of the Curculionidae

Basal wound—a wound at the base of a tree

Bole—the main trunk or stem of a tree

Boring dust—tiny particles of bark or wood produced by insects as they tunnel in woody plants

Branch flagging—a disease symptom where some of the foliage on branches, particularly older foliage, is dead or dying

Bracing—the installation of lag-threaded screws or rods in limbs, leaders, or trunks to provide supplemental support

Branch stub—the remnant of a tree branch after it breaks off near the bole; often an entrance point for decay fungi or a site where fungal conks form

Broom or **witches' broom**—an abnormal proliferation of branches or twigs on a single branch; can be associated with infection by dwarf mistletoe, rust fungus, genetic aberration, or other insect or disease

Burl—a tree growth in which the wood grain has grown in a deformed manner, most often appearing as a rounded swelling on a branch or bole

Butt—the base of a tree bole to a height of approximately 8–16 ft

Butt rot—decay developing in and sometimes confined to the base of the bole; can originate at basal wounds or extend upwards from roots

Cabling—the installation of a cable within a tree between limbs or leaders to limit movement and provide supplemental support

Callus—tissue produced at wound sites in response to injury that may or may not overgrow the damaged tissue

Cambium—layer of actively dividing cells between the xylem (sapwood) and the phloem (inner bark) of trees, which forms additional conducting tissue

Canker—an area of dead tissue on a stem, branch, or root usually caused by fungi, bacteria, or parasitic plants

Causal agent—a biotic (e.g., fungi, insects) or abiotic (e.g., wind, fire) entity that causes a deviation from the normal form or function of a tree

Conk—a shelflike reproductive structure formed by many wood decay fungi; also called a sporophore or fruiting body

Crack—separation of wood fibers creating breaks or fractures in stems and branches

Crown—canopy or branches and foliage extending from the main stem or bole

Cubical decay—decayed wood that breaks into distinct square or rectangular cubes

Decay—degradation or decomposition of wood by fungi and other microorganisms resulting in the progressive loss of integrity and strength of affected parts; can be incipient or advanced

Decay column—Internal section of a tree bole or branch that is decayed along its longitudinal axis

Defect—any feature, fault, or flaw that lowers the strength, integrity, or utility of an affected part

Delaminate—to separate into sheets as with the pages of a book; wood delaminates at the growth rings; characteristic of decay caused by *Coniferiporia sulphurascens* and other decay fungi

Diameter at breast height—the diameter of a tree at 4.5 feet above the ground on the uphill side of the tree; abbreviated as "DBH"

Disease—a prolonged disturbance of the normal form or function of a tree or its parts that is caused by organisms, such as fungi or mistletoes but not insects

Disease center—a group of dead and dying trees that have developed progressively over time; caused by root pathogens such as *Armillaria* spp. or *Coniferiporia sulphurascens*; also called a mortality center, infection center, or disease pocket

Dwarf mistletoe—a parasitic flowering plant with stems and seeds that develops extensive absorption systems in the xylem of conifers and derives nearly all its water and nourishment from its conifer host

Ectotrophic mycelium—fungal material, usually white to cream colored, found on the outside of the root bark formed by certain root pathogens (e.g., *Coniferiporia sulphurascens* and *Heterobasidion occidentale*)

Embedded (included) bark—the bark between branch forks or codominant stems that can act as a wedge, greatly weakening the fork union

Exposure—the state of being vulnerable to damage or harm by a hazard tree, regardless of outcome, by virtue of being in proximity to a potentially hazardous tree; the duration and frequency of exposure are used in determining the impact potential

Failure—partial or total breakage or collapse of a tree or tree part

Failure potential—the likelihood of a tree or its parts breaking, falling, or collapsing (refer to chapter 4 for ratings)

Failure zone—the area within which a tree or its parts will likely land in the event of failure (refer to chapter 2 for descriptions)

Frost crack—split in the outer bark and sapwood that occurs in the trunks of trees subjected to extreme cold and thawing; such fissures follow the grain and are usually superficial

Fruiting body—conk, mushroom, or other fungal reproductive structure that produces spores

Fungus (pl. fungi)—a member of the group of saprophytic or parasitic organisms that lack chlorophyll, have cell walls made of chitin, and reproduce by spores; includes molds, rusts, mildews, smuts, and mushrooms

Gall—a pronounced swelling or tumorlike growth, often round or pear shaped, produced on trees by insects, pathogens, or abiotic influences

Hazard tree—a tree or its parts that pose a risk of injury or damage to people or property and exceeds the risk tolerance of the responsible manager

Heart rot—decay usually restricted to the heartwood

Heartwood—the inner, nonliving, central part of a tree stem (bole) that provides chemical defense against decay and provides mechanical support

Hypha (pl. hyphae)—single, microscopic, threadlike filament that makes up the mycelium of a fungus

Impact potential—the likelihood that a tree or tree part could strike a target and the resulting damage that may occur; determined by evaluating both the level of exposure and the severity of possible damage or loss (refer to chapter 3 for ratings)

Incipient stain/decay—early stages of decay often characterized by darkened or discolored wood that appears water soaked or darkened

Increment borer—a type of auger with a hollow bit and an extractor used to remove thin radial cylinders of wood (increment cores) from trees to determine tree age or detect the presence of wood decay or stain

Infection—the act of a pathogen establishing itself on or within a host

Inoculum—infective propagules, such as spores or tissue of a pathogen, that serve to initiate disease

Mitigation—the action taken to reduce risk of damage or injury, such as closing sites, closing roads, moving targets, removing the defective tree or parts, etc.

Mycelium (pl. mycelia)—the collective mass of filamentous elements, or hyphae, of a fungus

Mycelial fan—a mass of hyphae that take the form of a thick, fan-shaped mat; usually thick enough to peel off like latex paint and are white to cream colored when fresh and turn brown when old, especially with *Armillaria* spp.

Mycelial felt—a dense mass of mycelium that takes the form of a thick sheet or mat

Mushroom—the reproductive fruiting (i.e., spore-producing) body of any fleshy fungus, usually produced annually

Occupancy—the frequency that a site is used by people for the intended or managed purpose

Pathogen—an organism, such as a fungus, parasitic plant, bacterium, or virus, capable of causing disease in a particular host or range of hosts

Pitch—a resinous exudate of various conifers

Pore—a small hole in the undersurface of a fungal fruiting body from which spores emanate

Pruning—the removal, close to the branch collar, of branches (live or dead) or multiple leaders from a standing tree

Pulaski—a chopping and trenching tool that combines a single-bitted ax blade with a narrow trenching blade that resembles an adz

Punk knot or swollen knot—a protruding and unhealed knobby growth on a tree with heart rot; the surface is not fully encased in bark, and the interior of the knobby growth contains highly decayed wood that resembles the interior of the conk of the causal fungus

Pustules—very small (less than ½ in wide) fruiting bodies that form on trees infected with rust fungi or *Heterobasidion* spp., especially on saplings or seedlings

Resin—secretions of certain trees, especially conifers, that are oxidation or polymerization products of terpenes, consisting of mixtures of aromatic acids and esters; generally associated with tree resistance to fungi and insects; also called pitch

Resinosis—the reaction of a tree to invasion by certain pathogens and insects or to abiotic injuries that results in the copious flow of resin over the outer bark in the area of injury, resin soaking within the outer bark, or in resin accumulation under the bark

Rind—the shell of solid wood surrounding a decay column in a tree; it may not be continuous because of a wound or canker

Risk—the probability that harm or loss will occur if exposed to a hazard; in trees, risk is the combination of the probability of tree failure (failure potential), the level of exposure, and the severity of possible damage or loss (target value)

Root collar—where the root system joins the bole at the base of a tree

Root sprung—trees with roots that are partially pulled out of the ground

Rust or rust fungus—a particular group of diseases or the fungi that cause them

Saprophyte—an organism that lives on dead organic matter

Sap rot—wood decay that is characteristically confined to the sapwood

Sapwood—the outer layers of wood between the heartwood and the bark; composed of xylem that conducts water up the tree

Scar—a wound that often shows some evidence of callus tissue (sealing)

Setal hyphae—thick-walled, reddish-brown hyphae found in advanced decay associated with laminated root rot; may be visible with the naked eye or under low magnification appearing as straight, hairlike structures

Shake—a physical defect of trees caused by exposure to high winds; appears in its most advanced stages as deep longitudinal fissures that follow the grain of the butt log and are associated with separations of the growth rings deep in the heartwood; growth ring separations often occur without the external fissures

Sign—physical evidence of a pathogen or insect, such as the presence of conks, setal hyphae, mycelial fans or felts, aerial shoots of mistletoes, or bark beetle galleries

Snag—a standing dead tree often classified by the degree of decay

Spore—a microscopic reproductive propagule of fungi

Stem—the main trunk or central stalk of a plant; also called a bole

Stress (distress) cone crop—an abundance of cones produced as the result of tree stress; often associated with root diseases

Structural roots—major tree roots that significantly add to the support of a standing tree

Symptom—how the host expresses disease, such as chlorotic foliage, premature loss of foliage, resinosis, brooms, and dead branches or tops

Target—people, property, or infrastructure that could be injured or damaged by failure of a tree or its parts

Topkill—death of the leader or upper crown of a tree; usually caused by insects, pathogens, animals, or weather

Topping—removal of some of the upper crown of a tree; not recommended for live crowns

Undermined roots—roots that are no longer firmly anchored due to soil removal or loss

Vascular wilt—symptom of a lack of water in a plant's vascular system whereby foliage loses its turgidity and droops (wilts); type or group of diseases caused by fungi, bacteria, or nematodes that disrupt or block water conduction in the xylem

Wetwood—wood in living trees that appears water soaked or stained, often has a foul odor, and is a symptom of colonization by bacteria; inhibits wood decay in affected trees

Windthrow—a tree that has fallen to the ground, usually at the roots or butt, due to excessive wind or perhaps without wind because of decayed roots or butt

Wound—an injury that usually breaks the bark of branches, the bole, or the roots of a tree and serves as a possible entry point for many species of fungi; may become sealed with new bark and eventually become hidden over time

Zone line—a narrow, dark-brown or black line in decayed wood, generally resulting from the interaction of different strains of fungi or the host reaction

PLEASE DON'T WOUND TREES

THANK YOU FOR
PROTECTING A HEALTHY FOREST
FOR ALL TO ENJOY!

Notes

Notes