February 6, 2023

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Submitted via email to: objections-southwestern-regional-office@usda.gov; objections-southwestern-kaibab@usda.gov

Re: OBJECTIONS to Mangum Fire Emergency Actions / Hazard Tree Removal Project Environmental Assessment (Kaibab National Forest), Pursuant to 36 C.F.R. § 218.8

To Forest Supervisor Branton and Regional Forester Martin:

The Center for Biological Diversity submits these objections to the U.S. Forest Service's Environmental Assessment ("EA") and draft Decision Notice for the *Mangum Fire Emergency Action / Hazard Tree Removal Project* ("Hazard Tree Project") on the Kaibab National Forest.

Project Objected To

Pursuant to 36 C.F.R. § 218.8(d)(4), Center for Biological Diversity *et al*. object to the following project:

> ***Project***: Mangum Fire Emergency Action / Hazard Tree Removal Project, Kaibab National Forest, North Kaibab Ranger District
>
> ***Responsible Official and Forest/Ranger District***: Randall Walker, District Ranger, North Kaibab Ranger District, Kaibab National Forest

Timeliness

Notice of the Draft Decision Notice and Final EA was published in the Flagstaff Daily Sun (the newspaper of record) on December 22, 2022, making the deadline for filing February 6, 2023. These objections are therefore timely filed.

Lead Objector

Per 36 C.F.R. § 218.8(d)(3), the Objectors designate the "Lead Objector" as follows:

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Interests and Participation of the Objectors

The Center for Biological Diversity is a non-profit environmental organization with more than 1.7 million members and online activists who value wilderness, biodiversity, old growth forests, and the threatened and endangered species which occur on America's spectacular public lands and waters. Center members and supporters use and enjoy the Kaibab National Forest and the lands proposed for logging within the Mangum Fire Emergency Action / Hazard Tree Removal Project area for recreation, photography, nature study, and spiritual renewal.

The Center has advocated, since the mid-1990s, for forest restoration that combines appropriate mechanical thinning, a right-scaled restoration industry, prescribed burning, and community protection while maintaining or enhancing large and old trees, key ecological process such as fire, and protecting sensitive and listed species.

The Center has been an active stakeholder throughout the project planning process. The Center submitted timely comments on the initial scoping on June 30, 2021, and on the Draft EA on August 12, 2022. We have toured the project area in December 2020, and participated in numerous discussions and field visits of the North Kaibab with the Forest Service and other stakeholders.

We support many of the changes and additions made in response to comments on the Draft EA. In particular, we support the reduction in roadside hazard tree removal by more than half of the 40 miles of roads initially proposed for treatment. We also support the clarification that treatment along trails and fences will not use motor vehicles and that felled trees will be left on site.

However, we must object to the removal of trees up to 200 feet from roads. We recognize the potential danger posed by hazard trees along open roads and trails and we support targeted mitigation of legitimate hazard trees, but the proposed action as designed violates NEPA and is not justified by the existing conditions or the purpose and need specified in the EA. Furthermore, the EA fails to adequately identify, disclose, and analyze the impacts of tree removal hundreds of feet away from roads.

OBJECTIONS

THE EA FAILS TO PROVIDE ADEQUATE JUSTIFICATION FOR REMOVING TREES 200 FEET FROM ROADWAYS.

The EA offers several rationales for requiring a buffer of 200 feet along all roads within areas of moderate and high burn severity. One is to protect the public, public, Forest Service personnel, contractors and permittees.[1] Another is to allow for restoration and re-planting along roads.[2] A third is to protect the effectiveness of roads as fuel breaks[3]. These rationales are logically flawed, contradictory, arbitrary and capricious.

[1] "The main reason buffer widths were chosen at 200-feet was to meet the intent of the purpose and need (see Section 2.3 "Purpose and Need for Action" above; a buffer width from the road should be effective enough to be free from hazard trees so as to protect the public, forest service personnel, contractors and permittees, as well as aid in re-establishment and protection of certain roads, trails, fence lines, and developed water features. By law (36 CFR 261.54) and as stated on the NKRD MVUM, motor vehicles may be parked up to 30-feet from the edge of the road surface (even outside designated camping corridors), which means a 100-foot from road buffer area would not meet the intent or the proposed action to lower risk within proposed treatment areas (see table 1)." EA at 14.

[2] "Restoration and/or possible re-planting of the 100-to-200-feet part of the buffer area is also a main consideration of choosing the 200-feet from road's edge width." EA at 14.

[3] "Besides the risk to public and worker safety from hazard trees, there is a risk of high fuel loads building up over time within the proposed treatment buffer areas. The "total" width of treatment areas along roads (200-foot-wide corridor versus a 400-foot-wide corridor) would not be as effective using a 100-feet from roads edge, as a fire-line or effective fire break, in the event of a future fire in adjacent forested areas. Heavy on-the-ground fuel loads will

A. Protecting the public, and the domino theory.

The EA provides the following example of the domino effect:

> "*The Arizona Department of Transportation's right-of-way width is 100 feet from centerline of the of the paved road (highway 89-A), therefore any hazard tree (100-feet or taller) still standing at the outer edge of the right-of-way has the capability of falling within the right-of-way and possibly hitting the road. This is the same with forest service roads. Larger diameter trees are taller and have more mass, thus the force is greater when they fall. Example: a 100-foot-tall Ponderosa pine hazard tree located 200 feet from the roads edge falls towards the road and hits a second 100-foot-tall hazard tree, which directed by the force of the first falling tree, also falls towards the road. So, the total distance covered through a domino effect (which is possible and still a risk to public and employee health and safety) could be up to 200 feet. Thus, to lower risk and increase the safety to public and employees utilizing roads adjacent to treatment areas, hazard trees need to be removed up to 200 feet from roads edge.*" EA at 15.

One problem with this example is that it does not represent a realistic situation consistent with the laws of physics. In this example, the first 100-foot-tall tree would fall at the base of the second tree, reaching its root collar with just the tip of its highest leader branchlet. It is physically impossible that this could cause the second tree to fall. Another problem is that the second tree in this example will fall only to the edge of the roadway, with just the tip of the highest leader branch touching the edge of the road prism. This is because the road buffer proposed in the Mangum Hazard Tree Project extends 200 feet from the edge of the roadway, rather than from the centerline from which the state right-of-way is measured. A further problem with this example is that most trees in the project area are significantly shorter than 100 feet in height. Thus, the domino effect could reach the roadway from 200 feet only if there are multiple trees in a line directly perpendicular to the road, so that each tree hits the next tree perfectly to perpetuate the domino effect, a scenario that is extremely unlikely, if not impossible.

Practically, the "domino effect" hypothesis serves to justify removal of *any* tree within 200 feet of the road, regardless of the actual hazard posed with respect to the road. The Mangum Hazard Tree Project identifies no criteria for determining hazard to the road—criteria such as whether a tree is tall enough to reach the road or, in the case of the domino effect, whether there is another tree between the first tree and the road, and whether the second tree could reach the road. The EA simply poses a hypothetical situation in the domino effect and thereafter takes the need for a 200-foot removal distance as given and universal.

The Ninth Circuit Court of Appeals in 2020 reviewed the Ranch Fire Roadside Hazard Tree Project on the Mendocino National Forest in California, a project quite similar to the Mangum Hazard Tree Project. The Ranch Fire project involved the post-fire removal of roadside hazard trees up to 200 feet from a road, applying the same "domino effect" rationale) on an area of 4,700 acres. The Court concluded that the public interest did not favor allowing the project to occur in part because "*the Project allows felling of trees that are at such a distance from roads that their tips will never come close to the edge of the road, even if the trees fall directly toward*

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continue to build up over time within the 100–200-foot intervals from roads, thus compromising the effectiveness of the hazard tree removal area for use as a fuel break, fire line, or for emergency egress (to and from) a fire / fire line, by fire personnel in the future." EA at 15.

the road at a 90 degree angle," and thus logging trees so far from roads would do little or nothing to protect public safety.[4] The court's decision underscores the arbitrary nature of the EA's proposed 200-foot buffer here.

As an additional rationale for a more expansive removal distance, the EA proposes that a 200-foot buffer will protect motor vehicles parked up to 30 feet from the road's edge and dispersed camping within designated areas.[5] This rationale is arbitrary for at least two reasons. First, the Mangum Hazard Tree Project includes far more roads than are designated as Motorized Dispersed Camping Corridors per the North Kaibab Ranger District Motor Vehicle Use Map, and instead applies this rationale to all roads in areas with moderate or high soil burn severity. Second, the protection of motor vehicles 30 feet from the road does not require the removal of hazard trees 200 feet from the road. It requires only the removal of hazard trees tall enough to reach within 30 feet of the road if the tree should fall directly perpendicular to the road.

The EA proposes that the 200-foot distance is a compromise between 100 feet for all roadways and 300 feet for designated dispersed camping corridors, to use a single operational prescription that provides a reasonable level of protection for both situations. We support the abandonment of the 300-foot distance, but this does not negate the negative environmental impacts of logging operations that extend significantly farther from roads than are necessary. Furthermore, the EA must specify the total area that is being impacted—and the results of those impacts—with the selection of a 200-foot removal distance. That is, the EA must disclose the difference in impacts that will occur as a result of a 200-foot distance as compared to removing only those hazard trees in a position to fall on a road or within 30 feet of a road. Such impacts include the additional loss of habitat, additional soil compaction, and the subsequent increased access to motor vehicles.

B. Restoration and Replanting Along Roads.

The EA states as a main objective the restoration and re-planting of trees along roads.[6] However, the EA fails to consider (1) that the overbroad application of a hazard tree definition will result in the removal of many trees that are structurally sound and likely to survive indefinitely, (2) that unnecessarily expansive hazard tree removal will result in the unnecessary destruction of natural regeneration, thereby requiring replanting that would otherwise be unnecessary, and (3) that replanting along roadways directly contradicts the stated goal of maintaining fuel breaks along those roads.

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[4] *Envtl. Prot. Info. Ctr. v. Carlson*, 968 F.3d 985, 992 (9th Cir. 2020). A copy of the decision is attached as Addendum A.

[5] "Additional consideration of utilizing 200-feet versus 100-feet because of the need for rehabilitation of some motorized disperse camping corridor areas, and because motorized vehicles can be parked up to 30- feet from the roads edge anywhere along roads outside the dispersed camping corridors. According to the current Motorized Vehicle Use Map (MVUM), some roads (FS Roads 275, 461G, 753, 773) in the ponderosa pine areas have designated motorized dispersed camping corridors (either 100-feet or 300-feet from roads edge), which need to be mitigated regarding hazard trees. (please refer to section 2.1.1 – "Hazard Trees Located Along MVUM Roads," table 1 and figure 8 above.) A 200-foot distance was chosen as a compromise for the 100-foot and 300-foot camping corridor areas. Within the 300-foot camping corridors, there will be some immediate relief following treatment, so as to allow safe vehicle or camp-trailer parking within a 200-foot treatment area.)" EA at 15.

[6] "Restoration and/or possible re-planting of the 100-to-200-feet part of the buffer area is also a main consideration of choosing the 200-feet from road's edge width." EA at 14.

The Final EA, in its response to comments in Appendix F, states the intention to adhere to the silviculture Best Management Practices for hazard trees.

> *"Specifically, the silviculture BMPs – for cutting, felling, and removal of hazard trees within burn areas lists the following: Retain live, green trees where possible and those with a good chance of survival. Trees with live crowns less than 25% should be cut and removed. Erosion would be avoided and mitigated by timing of the logging operations, staying off steeper slopes > 30%, and logging on frozen soils. Standing green trees (both ponderosa pine and pinyon-juniper) not considered as a hazard won't be cut according to the proposed action."* EA, Appendix F, Consideration of Preliminary EA Comments, at F-8.

The EA also repeatedly cites to Appendix A, "*What Constitutes a Danger or Hazard Tree*" as a primary guidance for hazard tree removal.[7] That document is clear in that it defines a hazard tree as a tree that has both of the following characteristics: "*1. A structural defect that increases the probability that the whole tree or tree parts will fail and 2. A target (e.g.. people, buildings, vehicles, etc) that could be hit when the tree or its parts do fail.*"[8]

Appendix A, in turn, refers to USDA-FS-R3; *Tree Risk Assessment and Hazard Tree Mitigation in the Southwestern Region*, June 2020. (84 pages) and General Technical Report PNW-GTR-769: *A Field Guide to Predict Delayed Mortality of Fire-Damaged Ponderosa Pine: Application and Validation of the Malheur Model*. October 2008.[9]

USDA-FS-R3 specifies the following criteria for post-fire removal of ponderosa pine:

> "*1. If no crown consumption is present, crown scorch affecting greater than 85% of the crown indicates 85-90% probability of mortality. 2. Crown consumption greater than 40% indicates 85-90% probability of mortality. 3. Crown consumption between 5 and 40% coupled with crown scorch > 50% indicates greater than 50% probability of mortality…. Most trees suffering 25% (one quadrant) or less cambium kill will survive, while trees suffering 75% or greater (3 quadrants) cambium kill have a high probability of mortality*." USDA-FS-R3 at 17-18.

Despite referencing these guidelines as the basis for the hazard tree selection, the Forest Service proposes to classify as a hazard tree any tree with less than 25% live crown, a standard that satisfies none of the criteria specified in USDA-FS-R3. In addition, the EA enumerates the following guidelines for hazard tree removal, in *Appendix E, Resource Protection Measures*.

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[7] "The intent of the EA is clearly stated several times throughout the EA, in that 'Trees deemed as a hazard tree should be removed.' Trees would be identified for removal as identified in accordance with the protocols outlines in the documents listed in Appendix A – 'What Constitutes a Danger or Hazard Tree'." EA, Appendix F, at F-8.

[8] EA, Appendix A, What Constitutes a Danger or Hazard Tree, one page.

[9] "Note the following documents and applicable definitions will be utilized in the implementation of the Mangum Fire Emergency Actions / Hazard Tree Removal Project: USDA-FS-R3; Tree Risk Assessment and Hazard Tree Mitigation in the Southwestern Region, June 2020. (84 pages): https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd757405.pdf... General Technical Report PNW-GTR-769: A Field Guide to Predict Delayed Mortality of Fire-Damaged Ponderosa Pine: Application and Validation of the Malheur Model. October 2008." EA, Appendix A. PNW-GTR-769 available at: https://www.fs.usda.gov/pnw/pubs/pnw_gtr769.pdf. These documents are attached as Addenda B and C.

*"**Silviculture BMPs - Cutting, felling, and Removal of Hazard Trees within Burn Areas***

The NKRD has design features to mitigate the effects of harvesting dead trees in a burned area, and subsequent reforestation. See bulleted items below:

- *Cut and remove hazard trees from the road prism extending 200-feet into the forest; buffer strip that is created on both sides of the road may function as a safety area and fuel break when the project is completed. Buffer strip would need to be created in a non-linear fashion at the outer edge of the hazard tree boundary away from road.*
- *Retain live, green trees where possible and those with a good chance of survival.*
- *Trees with live crowns less than 25% should be cut and removed.*
- *Continued drought over the past 18 months has severely stressed residual trees in the burn area, and these trees are very susceptible to bark beetle attack and should be removed.*
- *Remove trees with signs of bark beetle attack, especially pitch tubes, visible frass, and boring holes.*
- *When in doubt, exercise caution and remove the tree."*

These guidelines are confusing and vague in critical ways. The first point seems to indicate that the intention is not only to preserve the ability to create a fuel break along the road in the future, but to use the hazard tree removal to create a fuel break as part of this project. The difference is between removing trees that pose a real hazard versus removing all trees that can possibly be captured in the most expansive application of the definition of hazard tree. The bullet point on drought appears to state that all remaining trees are susceptible to bark beetle and, therefore, that all trees should be removed. Given the ambiguity of that statement, the subsequent statement that "*when in doubt, exercise caution and remove the tree*" would seem to urge the removal of all trees, regardless of apparent health status.

In addition to being unclear, the ambiguity of the prescription makes it impossible for the agency to satisfy NEPA's "hard look" requirements. As it is unclear which trees and how many trees will be removed, the EA is unable to disclose the project impacts in terms of, for example, how much logging will occur, the extent of ground disturbance, and the number and distribution of trees remaining along roads after the project.

Our concern, on reading these BMPs, is not about the dense stands of fire-killed trees presented in the photos appended to the final EA. Rather, our concern is regarding the remaining live trees, the stands where mortality is patchy and trees are spaced widely, and the trees that are in no danger of reaching another tree or the road. All of those could presumably be clearcut in the application of the BMPs.

For its part, PNW-GTR-769, also cited by the EA as a guidance for hazard tree removal, clearly states that the referenced hazard tree criteria are applicable only to the Pacific Northwest, south into northern California.[10] The North Kaibab Ranger District is located far outside of that region. Relying on this report does not represent the "hard look" or the use of "accurate scientific analysis" that NEPA requires. PNW-GTR-769 is also clear that the hazard tree criteria are

[10] "The geographic area of inference for using the Malheur model has been expanded north of the development stands and south into northern California." PNW-GTR-769 at 16.

predictive of the mortality within three years of a burn.[11] Beyond three years post-fire, the model is less relevant, as trees will either have survived or not. In fact, the study found that, by the fourth year, tree mortality in burned units was the same as on unburned units.[12]

The Mangum Fire occurred in the summer of 2020; the unit will be three years post-fire as of the summer of 2023. Instead of applying the arbitrary criteria of less than 25% live crown in the attempt to predict which trees are likely to die, the Forest Service could instead, by the summer of 2023 and afterward, simply identify as hazard trees those trees that are dead. For the most part, those trees that have survived post-fire and show active growth in the summer of 2023 are likely to survive. By proposing a removal standard of any tree with less than 25% live crown, the project will be removing many trees that are likely to survive indefinitely and do not constitute a real hazard.

On this point, our concern is primarily about the removal of live, old and large trees, greater than 18 inches diameter. In an area where fire has reduced the large tree component, within a broader area where the North Kaibab Ranger District is administering and planning many timber sales of large and old trees, the remaining live large and old trees within the Mangum Fire area are critical components of the landscape and the forest ecosystem.

Removing more trees than necessary—whether living or dead—will require more mechanical operations over a broader area, resulting in greater soil disturbance and the unnecessary destruction of existing natural regeneration. These impacts are contradictory to the stated goal of restoring and replanting the areas along roads.[13] The EA must consider these impacts in balance with the putative benefits of more intensive and more expansive hazard tree removal. Failing to do so fails to satisfy NEPA's requirement that the agency take a "hard look" at the impacts of the project and reasonable alternatives that could result in reduced environmental impacts.

C. Fuel breaks and fire lines.

The EA states as a main objective of hazard tree removal the need to preserve the areas along roadways as potential fuel breaks and fire lines.

> "*Besides the risk to public and worker safety from hazard trees, there is a risk of high fuel loads building up over time within the proposed treatment buffer areas. The "total" width of treatment areas along roads (200-foot-wide corridor versus a 400-foot-wide corridor) would not be as effective using a 100-feet from roads edge, as a fire-line or effective fire break, in the event of a future fire in adjacent forested areas. <u>Heavy on-the-ground fuel loads will continue to build up over time within the 100–200-foot intervals from roads, thus compromising the effectiveness of the hazard tree removal area for use as a fuel break, fire line, or for emergency egress (to and from) a fire / fire line, by fire personnel in the future.</u> (Please refer to Fire and Fuels section 4.3.2 "Current Need for Change," pp. 22-23 below.)"* EA at 15, emphasis in original.

[11] "There is good agreement between the delayed mortality predicted by the Malheur model and the mortality observed 3 years following the burn in the 10 validation stands." PNW-GTR-769 at 16.

[12] "During the fourth year, the percentage of mortality on burned units was not statistically different from that on nonburned units" PNW-GTR-769 from abstract.

[13] "Restoration and/or possible re-planting of the 100-to-200-feet part of the buffer area is also a main consideration of choosing the 200-feet from road's edge width." EA at 14.

The objective, as described in the above paragraph and on pages 22-23, is clearly to reduce the current and future on-the-ground fuel load and to reduce the likelihood of trees falling into the road. The first objective is to preserve the ability to use the areas along roadways as fuel breaks or fire lines, the second is to prevent fallen trees from blocking emergency egress and firefighter movement during a future fire. We support both of these objectives. However, as described in the previous section, those trees that have survived post-fire and show active growth by the summer of 2023 or later are likely to survive at the same rates as other actively growing trees. That is, large, live trees within 200 feet of the road are not likely to die and become either on-the-ground fuel or a roadblock. In other words, the fire and fuels objectives in no way justify the removal of living trees.

Furthermore, the stated objective of preserving the ability to use the areas along roadways as fuel breaks or fire lines is contradicted by the stated intention to replant those areas. In fact, large trees, whether living or dead, are far more fire resistant than are young trees, which also serve as ladder fuels.

Suggested remedies:

- Revise the prescription for hazard tree removal along roads to include (1) a hazard tree that can fall within 30 feet of the edge of the road if it falls perpendicular to the road, or (2) a hazard tree that that is sufficiently close to another hazard tree such that the first tree could reasonably cause the second tree to fall within 30 feet of the edge of the road. A dead 100-foot-tall tree that is 150 feet from the road, with no other hazard trees between that tree and the road, would not be a hazard tree.
- Revise the criteria for hazard trees to include live trees only if they have an evident structural defect specified as recent damage, significant leaning, or the presence of pitch tubes.
- Prepare a supplemental EA, subject to public comment, that analyzes the impacts of removing hazard trees up to 200 feet from the road as compared to removing only those trees tall enough to reach the road, including the impacts to soil and natural regeneration.
- If the Forest Service decides not to revise the proposed action in response to the issues raised in these comments, it should in any case consider an alternative that revises the criteria and prescription for hazard trees as described above. Such an alternative would illuminate the differences in impacts between the proposed 200-foot buffer and a more targeted approach that achieves the purpose and need while retaining live and large trees.

In taking the “hard look” at impacts that NEPA requires, an EA must “study, develop, and describe” reasonable alternatives to the proposed action.[14] The Tenth Circuit explains that this mandate extends to EAs as well as EISs. “A properly-drafted EA must include a discussion of appropriate alternatives to the proposed project.”[15] This alternatives analysis “is at the heart of the NEPA process, and is ‘operative even if the agency finds no significant environmental

[14] 42 U.S.C. § 4332(2)(C) & (E); 40 C.F.R. § 1508.9(b) (an EA “[s]hall include brief discussions . . . of alternatives”).

[15] *Davis v. Mineta*, 302 F.3d 1104, 1120 (10th Cir. 2002) (granting injunction where EA failed to consider reasonable alternatives).

impact.'"[16] Reasonable alternatives must be analyzed for an EA even where a FONSI is issued because "nonsignificant impact does not equal no impact. Thus, if an even less harmful alternative is feasible, it ought to be considered."[17] When an agency considers reasonable alternatives, it "ensures that it has considered all possible approaches to, and potential environmental impacts of, a particular project; as a result, NEPA ensures that the most intelligent, optimally beneficial decision will ultimately be made."[18]

In determining whether an alternative is "reasonable," and thus requires detailed analysis, courts look to two guideposts: "First, when considering agency actions taken pursuant to a statute, an alternative is reasonable only if it falls within the agency's statutory mandate. Second, reasonableness is judged with reference to an agency's objectives for a particular project."[19] Any alternative that is unreasonably excluded will invalidate the NEPA analysis. "The existence of a viable but unexamined alternative renders an alternatives analysis, and the EA which relies upon it, inadequate."[20] The agency's obligation to consider reasonable alternatives applies to citizen-proposed alternatives.[21]

Courts hold that an alternative may not be disregarded merely because it does not offer a complete solution to the problem.[22] Even if additional alternatives would not fully achieve the project's purpose and need, NEPA "does not permit the agency to eliminate from discussion or consideration a whole range of alternatives, merely because they would achieve only some of the purposes of a multipurpose project."[23] If a different action alternative "would only partly meet the goals of the project, this may allow the decision maker to conclude that meeting part of the goal with less environmental impact may be worth the tradeoff with a preferred alternative that has greater environmental impact."[24]

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[16] *Diné Citizens Against Ruining Our Env't v. Klein*, 747 F. Supp. 2d 1234, 1254 (D. Colo. 2010) (quoting *Greater Yellowstone Coal. v. Flowers*, 359 F.3d 1257, 1277 (10th Cir. 2004)). *See also W. Watersheds Project v. Abbey*, 719 F.3d 1035, 1050 (9th Cir. 2013) (in preparing EA, "an agency must still give full and meaningful consideration to *all* reasonable alternatives" (emphasis added) (internal quotation and citation omitted)); 40 C.F.R. § 1502.14 (describing alternatives analysis as the "heart of the environmental impact statement").

[17] *Ayers v. Espy*, 873 F. Supp. 455, 473 (D. Colo. 1994) (internal citation omitted).

[18] *Wilderness Soc'y v. Wisely*, 524 F. Supp. 2d 1285, 1309 (D. Colo. 2007) (quotations & citation omitted).

[19] *Diné Citizens Against Ruining Our Env't*, 747 F. Supp. 2d at 1255 (quoting *New Mexico ex rel. Richardson*, 565 F.3d at 709).

[20] *Id.* at 1256.

[21] *See Ctr. for Biological Diversity v. Nat'l Highway Traffic Safety Admin*., 538 F.3d 1172, 1217-19 (9th Cir. 2008) (finding EA deficient, in part, for failing to evaluate a specific proposal submitted by petitioner); *Colo. Envtl. Coal. v. Dombeck*, 185 F.3d 1162, 1171 (10th Cir. 1999) (agency's "[h]ard look" analysis should utilize "*public comment* and the best available scientific information") (emphasis added).

[22] *Natural Resources Defense Council, Inc. v. Morton*, 458 F.2d 827, 836 (D.C. Cir. 1972).

[23] *Town of Matthews v. U.S. Dep't. of Transp.*, 527 F. Supp. 1055 (W.D. N.C. 1981).

[24] *North Buckhead Civic Ass'n v. Skinner*, 903 F.2d 1533, 1542 (11th Cir. 1990).

The courts also require that an agency adequately and explicitly explain in the EA any decision to eliminate an alternative from further study.[25]

CONCLUSION

We appreciate your consideration of the information and issues raised in our previous comments and highlighted in this objection.

We request a meeting to discuss potential resolution of issues raised in this objection, pursuant to 36 C.F.R. § 218.11(a). We hope that the Forest Service will use the objection process and such a meeting as opportunities to engage with stakeholders, including the objectors here, to develop a project that is legally and ecologically sound.

Sincerely,

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Addenda

Addendum A. *Envtl. Prot. Info. Ctr. v. Carlson*, 968 F.3d 985, 992 (9th Cir. 2020).

Addendum B. USDA Forest Service, 2020. TP-R3-16-37. *Tree Risk Assessment and Hazard Tree Mitigation in the Southwestern Region.* 84 pages. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd757405.pdf

Addendum C. Walter G. Thies, Douglas J. Westlind, Mark Loewen, and Greg Brenner. USDA Forest Service, 2008. PNW-GTR-769. *A Field Guide to Predict Delayed Mortality of FireDamaged Ponderosa Pine: Application and Validation of the Malheur Model*. 22 pages.

[25] *See Wilderness Soc'y*, 524 F. Supp. 2d at 1309 (holding EA for agency decision to offer oil and gas leases violated NEPA because it failed to discuss the reasons for eliminating a "no surface occupancy" alternative); *Ayers*, 873 F. Supp. at 468, 473.

Envtl. Prot. Info. Ctr. v. Carlson

United States Court of Appeals for the Ninth Circuit

May 27, 2020, Argued and Submitted, San Francisco, California; August 3, 2020, Filed

No. 19-17479

Reporter
968 F.3d 985 *; 2020 U.S. App. LEXIS 24341 **; 50 ELR 20183; 2020 WL 4433123

ENVIRONMENTAL PROTECTION INFORMATION CENTER, Plaintiff-Appellant, v. ANN CARLSON, in her official capacity as the Forest Supervisor of the Mendocino National Forest; UNITED STATES FOREST SERVICE, Defendants-Appellees, SIERRA PACIFIC INDUSTRIES, Intervenor-Defendant-Appellee.

Subsequent History: Rehearing denied by, Rehearing denied by, En banc *Envtl. Prot. Info. Ctr. v. Carlson, 2020 U.S. App. LEXIS 33871 (9th Cir. Cal., Oct. 27, 2020)*

Prior History: [1]** Appeal from the United States District Court for the Northern District of California. D.C. No. 3:19-cv-06643-EMC. Edward M. Chen, District Judge, Presiding.

Envtl. Prot. Info. Ctr. v. Carlson, 424 F. Supp. 3d 703, 2019 U.S. Dist. LEXIS 209258, 2019 WL 6525683 (N.D. Cal., Dec. 4, 2019)

Disposition: REVERSED and REMANDED.

Core Terms

Forest, feet, logging, roads, repair and maintenance, height, district court, felling, hazard, preliminary injunction, public interest, salvage, environmental, acres, burned, prepare, merits, categorical, declaration, eligible, tips, project area, authorizes, modifier, irreparable harm, public safety, injunction, distance, dead, agency's action

Case Summary

Overview

HOLDINGS: [1]-The district court erred in denying an environmental group's request for a preliminary injunction and in finding that the Forest Service's fire roadside hazard tree project qualified for the categorical exclusion (CE) for road repair and maintenance because, while felling a dangerous dead or dying tree right next to the road came within the scope of the "repair and maintenance" CE, under no reasonable interpretation of its language did the project come within the CE for "repair and maintenance" of roads, and the Forest Service did not show that fulfilling its obligation to prepare an environmental impact statement under *42 U.S.C.S. § 4332(2)(C)* or an environment assessment was inconsistent with the goal of public safety.

Outcome

Order reversed and matter remanded.

LexisNexis® Headnotes

Environmental Law > Assessment & Information Access > Environmental Assessments

HN1[] **Assessment & Information Access, Environmental Assessments**

The National Environmental Policy Act (NEPA) requires that federal agencies perform environmental analysis before taking any major Federal actions significantly affecting the quality of the human environment. *42 U.S.C.S. § 4332(2)(C)*. When the Government conducts an activity, NEPA itself does not mandate particular results. Instead, NEPA imposes only procedural requirements to ensure that the agency, in reaching its decision, will have available, and will carefully consider, detailed information concerning significant environmental impacts.

Business & Corporate Compliance > ... > Environmental Law > Assessment & Information Access > Environmental Impact Statements

Environmental Law > Assessment & Information Access > Audits & Site Assessments

Environmental Law > Assessment & Information Access > Environmental Assessments

HN2[] Environmental & Natural Resources, Environmental Impact Statements

An agency can comply with the National Environmental Policy Act in three ways. It can prepare an environmental impact statement (EIS); it can prepare an environmental assessment (EA); or it can invoke a categorical exclusion (CE). An EIS is the most searching review. It is required for any action "significantly affecting the quality of the human environment." *42 U.S.C.S. § 4332(2)(C)*. An EA is less searching. Its central function is to determine whether an EIS is required. 40 C.F.R. § 1508.9. A CE allows an agency to avoid preparing either an EIS or an EA. CEs are appropriate for "actions which do not individually or cumulatively have a significant effect on the human environment and which have been found to have no such effect." 40 C.F.R. § 1508.4.

Environmental Law > Natural Resources & Public Lands > National Environmental Policy Act

HN3[] Natural Resources & Public Lands, National Environmental Policy Act

Neither a case file and decision memo nor a supporting record is required in order to invoke the a categorical exclusion under *36 C.F.R. § 220.6(d)(4)*.

Environmental Law > Natural Resources & Public Lands > National Environmental Policy Act

HN4[] Natural Resources & Public Lands, National Environmental Policy Act

A case file and decision memo and a supporting record are required in order to invoke a categorical exclusion under *36 C.F.R. § 220.6(e)(13)*.

Civil Procedure > ... > Injunctions > Grounds for Injunctions > Balance of Hardships

Civil Procedure > Remedies > Injunctions > Preliminary & Temporary Injunctions

Civil Procedure > ... > Injunctions > Grounds for Injunctions > Likelihood of Success

HN5[] Grounds for Injunctions, Balance of Hardships

When deciding whether to issue a preliminary injunction, a district court considers whether the requesting party has shown (1) that he is likely to succeed on the merits; (2) that he is likely to suffer irreparable harm in the absence of preliminary relief; (3) that the balance of equities tips in his favor; and (4) that an injunction is in the public interest. Likelihood of success on the merits is a threshold inquiry and is the most important factor.

Civil Procedure > Appeals > Standards of Review > Abuse of Discretion

Civil Procedure > Remedies > Injunctions > Preliminary & Temporary Injunctions

Civil Procedure > Appeals > Standards of Review > De Novo Review

Civil Procedure > Appeals > Standards of Review > Questions of Fact & Law

HN6[] Standards of Review, Abuse of Discretion

Circuit courts review a grant or denial of a preliminary injunction for abuse of discretion. A district court's interpretation of the underlying legal principles, however, is subject to de novo review and a district court abuses its discretion when it makes an error of law. Under the abuse-of-discretion standard, as long as the district court got the law right, it will not be reversed simply because the appellate court would have arrived at a different result if it had applied the law to the facts of the case.

Business & Corporate Compliance > ... > Environmental Law > Assessment & Information Access > Environmental Impact Statements

Environmental Law > Assessment & Information Access > Audits & Site Assessments

Environmental Law > Assessment & Information Access > Environmental Assessments

HN7[] **Environmental & Natural Resources, Environmental Impact Statements**

The rationale for a categorical exclusion is that a project that will have only a minimal impact on the environment should be allowed to proceed without an environmental impact statement or and an environmental assessment.

Civil Procedure > ... > Injunctions > Grounds for Injunctions > Irreparable Harm

Environmental Law > Administrative Proceedings & Litigation > Remedies > Damages

HN8[] **Grounds for Injunctions, Irreparable Harm**

Ongoing harm to the environment constitutes irreparable harm warranting an injunction. When a project may significantly degrade some human environmental factor, injunctive relief is appropriate. Environmental harm can seldom be adequately remedied by money damages and is often permanent or at least of long duration, i.e., irreparable.

Civil Procedure > ... > Injunctions > Grounds for Injunctions > Balance of Hardships

Civil Procedure > ... > Injunctions > Grounds for Injunctions > Public Interest

HN9[] **Grounds for Injunctions, Balance of Hardships**

When the government is a party, appellate courts consider the balance of equities and the public interest together. If irreparable environmental injury is sufficiently likely, the balance of harms will usually favor the issuance of an injunction to protect the environment.

Summary:

SUMMARY**

Environmental Law

The panel reversed the district court's order denying Environmental Protection Information Center ("EPIC")'s request for a preliminary injunction, challenging the United States Forest Service's approval of the Ranch Fire Roadside Hazard Tree Project in Northern California (the "Project").

The Project authorized the Forest Service to solicit bids from private logging companies for the right to fell and remove large fire-damaged trees up to 200 feet from either side of roads in the Mendocino National Forest. Under the *National Environmental Policy Act*, rather than preparing an Environmental Assessment or an Environmental Impact Statement for the Project, the Forest Service relied on a categorical exclusion ("CE") for road repair and maintenance in *36 C.F.R. § 220.6(d)(4)*.

The panel discussed the requirements for a preliminary injunction. First, the panel held that EPIC was likely to succeed on the merits of its claim that the Forest Service erred in relying on the CE for road repair and maintenance. The panel noted **[**2]** that the rationale for a CE was that a project that will only have a minimal impact on the environment should be allowed to proceed without an environmental impact statement or an environmental assessment. The CE upon which the Forest Service relied authorized projects for such things as grading and resurfacing of existing roads, cleaning existing culverts, and clearing roadside brush. The panel concluded that under no reasonable interpretation of the language of *36 C.F.R. § 220.6(d)(4)* did the Project come within the CE for "repair and maintenance" of roads. Second, the panel held that EPIC submitted evidence of irreparable, although limited, harm. Third, the panel held that the balance of equities and the

** This summary constitutes no part of the opinion of the court. It has been prepared by court staff for the convenience of the reader.

public interest weighed in EPIC's favor. The panel reversed the denial of the requested preliminary injunction, and remanded for further proceedings.

Judge Lee dissented. He would hold that the district court did not abuse its discretion in denying EPIC's request for a preliminary injunction, and he would defer to the agency's actions within its expertise.

Counsel: Matt Kenna (argued), Public Interest Environmental Law, Durango, Colorado; René P. Voss, Natural Resources Law, San Anselmo, California; for Plaintiff-Appellant. **[**3]**

Jeffrey Bossert Clark (argued), Assistant Attorney General; Eric Grant, Deputy Assistant Attorney General; Sally J. Sullivan, John P. Tustin, and Jeffrey S. Beelaert, Attorneys; Environment and Natural Resources Division, Washington, D.C.; for Defendants-Appellees.

Sara Ghafouri (argued) and Lawson E. Fite, American Forest Resource Council, Portland, Oregon; Tyler Welti, Venable LLP, San Francisco, California; for Intervenor-Defendant-Appellee.

Judges: Before: William A. Fletcher and Kenneth K. Lee, Circuit Judges, and Benjamin H. Settle, [*] District Judge. Opinion by Judge W. Fletcher; Dissent by Judge Lee.

Opinion by: William A. Fletcher

Opinion

[*987] W. FLETCHER, Circuit Judge:

In July 2018, the Ranch Fire burned more than 400,000 acres in Northern California, including almost 300,000 acres in the Mendocino National Forest. After the fire, the United States Forest Service approved the Ranch Fire Roadside Hazard Tree Project (the "Project"). The Project authorizes the Forest Service to solicit bids from private logging companies for the right to fell and remove large fire-damaged trees up to 200 feet from either side of roads in the National Forest. Rather than preparing an Environmental Assessment ("EA") or an Environmental **[**4]** Impact Statement ("EIS") for the Project, the Forest Service relied on a categorical exclusion ("CE") for road repair and maintenance in *36 C.F.R. § 220.6(d)(4)*. Plaintiff Environmental Protection Information Center ("EPIC") challenges the Forest Service action, contending that the Project does not qualify for the exclusion. The district court agreed with the Forest Service, holding that the Project qualified for the exclusion, and denied a preliminary injunction. We reverse and remand.

I. Statutory and Regulatory Framework

HN1[] The *National Environmental Policy Act ("NEPA")* "requires that federal agencies perform environmental analysis before taking any 'major Federal actions significantly affecting the quality of the human environment.'" *Ctr. for Biological Diversity v. Salazar, 706 F.3d 1085, 1094 (9th Cir. 2013)* (quoting NEPA at *42 U.S.C. § 4332(2)(C)*). **[*988]** "When the Government conducts an activity, NEPA itself does not mandate particular results. Instead, NEPA imposes only procedural requirements to ensure that the agency, in reaching its decision, will have available, and will carefully consider, detailed information concerning significant environmental impacts." *Winter v. Nat. Res. Def. Council, 555 U.S. 7, 23, 129 S. Ct. 365, 172 L. Ed. 2d 249 (2008)* (internal quotation marks and citations omitted).

HN2[] An agency can comply with NEPA in three ways. It can prepare an EIS; it can prepare an EA; or it **[**5]** can invoke a CE. An EIS is the most searching review. It is required for any action "significantly affecting the quality of the human environment." *42 U.S.C. § 4332(2)(C)*. An EA is less searching. Its central function is to determine whether an EIS is required. 40 C.F.R. § 1508.9. A CE allows an agency to avoid preparing either an EIS or an EA. CEs are appropriate for "actions which do not individually or cumulatively have a significant effect on the human environment and which have been found to have no such effect." 40 C.F.R. § 1508.4.

II. Stated Purpose and Criteria of Project

According to Ann D. Carlson, Forest Supervisor for the Mendocino National Forest, "The primary purpose of the Project is to reduce current and potential safety hazards along roads [in the National Forest] to create a safe transportation system. . . . [T]he Project plans to remove hazard trees through a series of salvage sales." Carlson stated in a declaration in the district court that the Project's "[r]oadside hazard treatments involve removing

[*] The Honorable Benjamin H. Settle, United States District Judge for the Western District of Washington, sitting by designation.

only trees that constitute hazards to the selected roads . . . and that have the potential to reach roadways."

The vegetation in the burned area of the Mendocino National Forest comprises a variety of forest types, including **[**6]** mixed conifer, oak woodlands, pine, and Douglas fir. A logging company whose bid has been accepted may fell "merchantable hazard trees" of fourteen or more inches diameter at breast height ("DBH") that are "within one and a half tree-heights" of the road. Any tree within 200 feet of the centerline of the road that has been partially burned and has a 50 percent or higher probability of mortality is eligible for felling. For "the roads that run adjacent to the Snow Mountain Wilderness," the Project allows cutting of eligible trees within 100, rather than 200, feet of the centerline. In total, the Project authorizes the logging of millions of board feet of timber on nearly 4,700 acres of National Forest land.

Anthony Saba, a forester/silviculturist employed by the Forest Service, stated in a declaration that merchantable trees in the Project areas range from 60 to 185 feet in height. According to Saba, in one area of the Project, the average tree height is 100 feet; in another, the average height is 111 feet. Under the criteria of the Project, a logging company may cut a 100-foot tree located as far as 150 feet from the road, or a 111-foot tree located as far as 166 feet from the road. **[**7]** At the outer limit of the Project area, a company may cut even taller trees. If a 100-foot tree located 150 feet from the road were to fall directly toward the road at a 90 degree angle, the tip of the tree would come to the ground 50 feet from the road. If a 111-foot tree located 165 feet from the road were to fall in the same manner, its tip would come to the ground 54 feet from the road. If the trees were to fall at any other angle, their tips would come to the ground at greater distances from the centerline.

III. Categorical Exclusions

There are two categorical exclusions potentially relevant to the Project. One is for **[*989]** "repair and maintenance" of roads in the National Forest. The other is for "salvage" logging of "fire-damaged trees" on tracts of 250 acres or less. The Forest Service prepared neither an EIS nor an EA for the Project. Instead, it relied on the first CE.

The first CE covers:

> (4) Repair and maintenance of roads, trails, and landline boundaries. Examples include but are not limited to:
>
> > (i) Authorizing a user to grade, resurface, and clean the culverts of an established NFS road;
> > (ii) Grading a road and clearing the roadside of brush without the use of herbicides;
> >
> > (iii) Resurfacing **[**8]** a road to its original condition;
> > (iv) Pruning vegetation and cleaning culverts along a trail and grooming the surface of the trail; and
> > (v) Surveying, painting, and posting landline boundaries.

36 C.F.R. § 220.6(d)(4). ***HN3***[] Neither a "case file and decision memo" nor a "supporting record" is required in order to invoke the CE under *§ 220.6(d)(4)*.

The second CE covers:

> (13) Salvage of dead and/or dying trees not to exceed 250 acres, requiring no more than 1/2 mile of temporary road construction. The proposed action may include incidental removal of live or dead trees for landings, skid trails, and road clearing. Examples include, but are not limited to:
>
> > (i) Harvest of a portion of a stand damaged by a wind or ice event and construction of a short temporary road to access the damaged trees, and
> > (ii) Harvest of fire-damaged trees.

36 C.F.R. § 220.6(e)(13). ***HN4***[] A "case file and decision memo" and a "supporting record" are required in order to invoke the CE under *§ 220.6(e)(13)*.

IV. Procedural Background

EPIC filed suit in federal district court on October 16, 2019, contending that the Project does not qualify for the road maintenance and repair CE. As of November 21, 2019, logging had begun in two areas of the Project, and the Forest Service had finalized bidding on a third area. **[**9]** Bidding had not yet begun on the other areas in the Project. The district court entered a temporary restraining order ("TRO") pending its hearing on EPIC's request for a preliminary injunction. On December 4, 2019, the court denied the preliminary injunction and lifted the TRO. EPIC appealed, and we set an accelerated briefing schedule. We heard oral argument on May 27, 2020.

V. Standard of Review

HN5[] When deciding whether to issue a preliminary injunction, a district court considers whether the requesting party has shown "[1] that he is likely to succeed on the merits, [2] that he is likely to suffer irreparable harm in the absence of preliminary relief, [3] that the balance of equities tips in his favor, and [4] that an injunction is in the public interest." *Winter, 555 U.S. at 20*. Likelihood of success on the merits is a threshold inquiry and is the most important factor. *See, e.g., Edge v. City of Everett, 929 F.3d 657, 663 (9th Cir. 2019)*.

HN6[] We review a grant or denial of a preliminary injunction for abuse of discretion. *See, e.g., United States v. California, 921 F.3d 865, 877 (9th Cir. 2019)*. "The district court's interpretation of the underlying legal principles, however, is subject to de novo review and a district court abuses its discretion when it makes an error of law." *Sw. Voter Registration Educ. Project v. Shelley, 344 F.3d 914, 918 (9th Cir. 2003)* (en banc). Under the abuse-of-discretion standard, **[**10]** "as long as the district **[*990]** court got the law right, it will not be reversed simply because the appellate court would have arrived at a different result if it had applied the law to the facts of the case." *Melendres v. Arpaio, 695 F.3d 990, 999 (9th Cir. 2012)* (citations and alterations omitted).

VI. Discussion

A. Likely Success on the Merits

With respect to the Project at issue, the CE for road repair and maintenance is unambiguous. The CE applies to "repair and maintenance of roads, trails, and landline boundaries." "Repair" and "maintenance" are common words with well-understood ordinary meanings. In order to ensure that these words are understood in accordance with their ordinary meanings rather than as terms of art, the CE provides examples. "Repair and maintenance" of roads include "grad[ing], resurfac[ing], and clean[ing] the culverts" of a road; "grading a road"; "clearing the roadside of brush without the use of herbicides"; and "resurfacing a road to its original condition." *36 C.F.R. § 220.6(d)(4)(i)-(iii)*. The CE specifies that the "repair and maintenance" are not limited to these examples, but the clear inference (even without invoking the principle of ejusdem generis), is that other examples should be similar in character to the examples provided.

The question **[**11]** before us is whether an extensive commercial logging project that includes felling large, partially burned "merchantable" trees—including 100- and 111-foot trees located 150 and 166 feet from roads, as well as taller trees even farther away—is "repair and maintenance" within the meaning of *§ 220.6(d)(4)*. In her declaration in the district court seeking to justify the "repair and maintenance" CE, Forest Supervisor Carlson repeatedly referred to all the trees to be felled under the Project as "hazard trees." While all of the trees within the scope of the Project may be hazardous in some sense, many of them pose no imminent hazard. As described above, a number of the trees will not come close to the road even if they fall directly toward it.

We have no doubt that felling a dangerous dead or dying tree right next to the road comes within the scope of the "repair and maintenance" CE. But the Project allows the felling of many more trees than that. ***HN7***[] The rationale for a CE is that a project that will have only a minimal impact on the environment should be allowed to proceed without an EIS or and EA. The CE upon which the Forest Service relies authorizes projects for such things as grading and resurfacing **[**12]** of existing roads, cleaning existing culverts, and clearing roadside brush. A CE of such limited scope cannot reasonably be interpreted to authorize a Project such as the one before us, which allows commercial logging of large trees up to 200 feet away from either side of hundreds of miles of Forest Service roads.

Plaintiff EPIC argues that the CE for salvage logging, *36 C.F.R. § 220.6(e)(13)*, is the only potentially applicable CE for salvage logging of fire-damaged trees. According to EPIC, no project that allows salvage logging over an area that exceeds 250 acres is eligible for a CE. At an earlier time, when the salvage logging CE was first adopted, the Forest Service may have agreed with this position, as EPIC contends. But it is clear that even if it once agreed, the Forest Service no longer agrees. The current position of the Forest Service is that the CEs for road repair and maintenance and for salvage logging overlap. That is, in the view of the Forest Service, if a project that allows felling of dangerous trees near roads comes within the CE for repair and maintenance, that CE is available even if the total area of the project is greater than 250 acres.

[*991] In the case before us, we need not go so far **[**13]** as EPIC's argument would take us. The Project does not target only trees that pose an immediate danger to travelers. We therefore need not decide the question that would be presented, for example, if a post-fire salvage logging project allowed felling of dead and dying trees up to only 20 feet back from 100 miles of Forest Service roads, such that the area covered by the project would be more than 250 acres. Nothing close to that question is now before us.

The Project at issue provides substantial revenue to the Forest Service. It allows logging of commercially valuable trees up to 200 feet on either side of the road; allows felling of partially burned trees that have a 50 percent or higher chance of mortality; allows felling of large trees at such distances from the road that their tips will be 50 or more feet from the road even if the tree falls directly toward the road; and allows logging over an area of approximately 4,700 acres. Under no reasonable interpretation of its language does the Project come within the CE for "repair and maintenance" of roads.

B. Irreparable Harm

HN8[] "Ongoing harm to the environment constitutes irreparable harm warranting an injunction. When a project may significantly **[**14]** degrade some human environmental factor, injunctive relief is appropriate." *Southeast Alaska Conservation Council v. U.S. Army Corps of Eng'rs, 472 F.3d 1097, 1100 (9th Cir. 2006)* (internal quotation marks and citations omitted); *see also* *Amoco Prod. Co. v. Vill. of Gambell, 480 U.S. 531, 545, 107 S. Ct. 1396, 94 L. Ed. 2d 542 (1987)* (noting that environmental harm "can seldom be adequately remedied by money damages and is often permanent or at least of long duration, i.e., irreparable").

Kimberly Baker, a member of EPIC, submitted an affidavit in the district court stating that her enjoyment of the National Forest will be diminished if extensive logging were to occur for 200 feet on either side of the roads running through the burned area of the National Forest, as would be allowed under the Project. She wrote, "[I]f the Forest Service were to prepare an Environmental Assessment or Environmental Impact Statement, it would have to include alternatives to the planned logging. Alternatives . . . could include leaving the living trees standing, retaining more trees on the downhill side of the road and some of the downed hazard logs on the ground, which would be extremely helpful to wildlife and soil health and improve my enjoyment of the affected areas if such alternatives were chosen." Baker also submitted two research articles addressing the effects of logging on post-fire landscapes. **[**15]**

C. Balance of Equities and the Public Interest

HN9[] When "the government is a party, we consider the balance of equities and the public interest together." *California v. Azar, 911 F.3d 558, 581 (9th Cir. 2018)*. If irreparable environmental injury "is sufficiently likely," as in this case, "the balance of harms will usually favor the issuance of an injunction to protect the environment." *Amoco Prod. Co., 480 U.S. at 545*. We conclude that the balance of the equities and the public interest weigh in EPIC's favor.

The Forest Service argues that the balance of equities and the public interest favor it rather than EPIC. It contends that the harm suffered by EPIC and its members is relatively minor. The area covered by the Project is on either side of roads in the burned areas of the National Forest and is therefore easily visible to virtually **[*992]** all visitors to the Forest, but the Forest Service points out that it comprises only 1.6 percent of the total burn area. On the other side of the ledger, the Forest Service argues the balance of equities and the public interest favor the Service "because [the Project] seeks to reduce the threat to public safety and to preserve long-term forest health."

We of course agree with the Forest Service that public safety is important. In part, the Project **[**16]** serves that interest directly, to the extent that some of the trees that would be felled are undoubtedly dangerous to travelers. But as discussed above, the Project allows felling of trees that are at such a distance from roads that their tips will never come close to the edge of the road, even if the trees fall directly toward the road at a 90 degree angle. Further, commercial logging companies working under the Project will not fell hazardous trees smaller than 14 inches DBH, even if the trees are right next to the road. But the Project also indirectly serves the interest of public safety. As Forest Supervisor Carlson points out in her declaration, revenue from the Project will allow the Forest Service to pay for the felling of such trees. This is a valid and important point, but we note the obvious: A budgetary system that requires the authorization of commercial salvage logging operations in order to finance work necessary for public safety can put the Forest Service in an awkward and conflicted position in deciding whether, and under what conditions, to authorize such operations. *See* *Earth Island Inst. v. U.S. Forest Serv., 351 F.3d 1291, 1309 (9th Cir. 2003)* (Noonan, J., concurring).

We also of course agree with the Forest Service that the preservation **[**17]** of long-term forest health is important. We are not in a position to second-guess the Forest Service as to whether the logging authorized by the Project furthers that goal, and we defer to the Forest Service's considered judgment that it does.

In the end, however, we are not persuaded that public safety will actually be put at risk by granting the relief EPIC seeks. EPIC has never denied the Forest Service's right to rely on the CE for road repair and maintenance in order to fell trees next to the road that pose an immediate danger to users of the road. To the extent the Forest Service authorizes salvage logging that constitutes more than repair and maintenance, EPIC seeks only the preparation of an EIS or an EA. The Forest Service has not shown that fulfilling its obligation to prepare an EIS or an EA is inconsistent with the goal of public safety.

The public interest is served by requiring the Forest Service to comply with the law. We have concluded, above, that the Project does not qualify for the CE for road maintenance and repair. The Forest Service must therefore prepare either an EIS or an EA.

Conclusion

We conclude that EPIC will succeed on the merits of its claim; that it will **[**18]** suffer irreparable, though limited, harm; and that it has demonstrated that the balance of equities and the public interest weigh in its favor. We therefore reverse the district court's denial of the requested preliminary injunction and remand for further proceedings not inconsistent with this opinion.

REVERSED and **REMANDED**.

Dissent by: Kenneth K. Lee

Dissent

LEE, Circuit Judge, dissenting:

The Ranch Fire Roadside Hazard Tree Project (the "Project") may not be optimally designed for the reasons outlined by the majority. But big problems often require big and imperfect solutions. And under a deferential standard of review, we should not second-guess an imperfect plan **[*993]** fashioned by the United States Forest Service, even if we could have crafted a better tailored one.

The Ranch Fire burned nearly 410,000 acres of land, earning its title as the largest wildfire in California's history. About 288,000 acres of the burned area is in the Mendocino National Forest. Over 770 miles of public roads that allow visitors to access the Forest for recreation and respite are now threatened by charred trees, some of which tower over the landscape up to 185 feet in height. If these trees fell on public roads, the lives of visitors, **[**19]** first responders, and United States Forest Service personnel would be placed in grave danger.

The Forest Service responded with an imperfect but workable solution: Salvage operators will remove at their expense dying trees that threaten high-priority roadways and pay the Forest Service for that privilege. The Project's criteria are sufficiently strict, requiring operators to remove only what is reasonably necessary to further road safety and maintenance. Trees eligible for removal must be 14 inches in diameter at breast height, they must be within one and a half times their individual height distance from the road, and they must have a 50% or greater likelihood of mortality. In other words, eligible trees must be large, able to strike the road, and at least halfway dead. According to the declaration of Mendocino National Forest Supervisor Ann Carlson, timber sales are the primary means to fell thousands of hazardous trees because it is "highly unlikely" that the Service "could obtain sufficient appropriated funds [from Congress] to accomplish all project activities." The Forest Service estimates that the cost to the agency would be about $5.5 million otherwise.

While I share majority's **[**20]** concerns about some aspects of the Project, I respectfully dissent because we must defer to the Forest Service's plausible plan and the district court's denial of preliminary injunction.

* * * *

Our review is limited by a double dosage of deference. First, we review the district court's denial of a preliminary injunction for abuse of discretion. *See* *United States v. California, 921 F.3d 865, 877 (9th Cir. 2019)*. This is a highly deferential standard. A district court's decision "will not be reversed simply because the appellate court would have arrived at a different result if it had applied the law to the facts of the case." *Melendres v. Arpaio, 695 F.3d 990, 999 (9th Cir. 2012)* (citations and alterations omitted).

Second, we need to be mindful that our review is further limited in a challenge to an agency action. Under the *Administrative Procedure Act*, "[a]n agency's determination that a particular action falls within one of its categorical exclusions is reviewed under the arbitrary and capricious standard." *Alaska Ctr. for the Env't v. USFS, 189 F.3d 851, 857 (9th Cir. 1999)*. Courts uphold agency action unless it is "arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law." *5 U.S.C. § 706(2)(A)*. The standard is "highly deferential, presuming the agency action to be valid and affirming the agency action if a reasonable basis exists for its decision." *Ranchers Cattlemen Action Legal Fund United Stockgrowers of Am. v. USDA, 499 F.3d 1108, 1115 (9th Cir. 2007)* **[**21]** (citation and internal quotation marks omitted). A court considers whether "the evidence in the administrative record permitted the agency to make the decision it did." *Occidental Eng'g Co. v. INS, 753 F.2d 766, 769 (9th Cir. 1985)*. Above all else, "we do not substitute our judgment for that of the agency." *N. Plains Res. Council, Inc. v. Surface Transp. Bd., 668 F.3d 1067, 1074 (9th Cir. 2011)* (internal citation omitted).

[*994] The district court did not abuse its discretion in denying EPIC's requested preliminary injunction.

Plaintiffs seeking a preliminary injunction carry a heavy burden. A plaintiff must show "[1] that he is likely to succeed on the merits, [2] that he is likely to suffer irreparable harm in the absence of preliminary relief, [3] that the balance of equities tips in his favor, and [4] that an injunction is in the public interest." *Winter v. Nat. Res. Def. Council, 555 U.S. 7, 20, 129 S. Ct. 365, 172 L. Ed. 2d 249 (2008)*. As the majority notes, likelihood of success on the merits is most important and typically dispositive. *See* *Edge v. City of Everett, 929 F.3d 657, 663 (9th Cir. 2019)*. When, as here, "the government is a party, we consider the balance of equities and the public interest together." *California v. Azar, 911 F.3d 558, 581 (9th Cir. 2018)*.

1. *The district court did not abuse its discretion in finding that EPIC did not show a likelihood of success on the merits*.

The majority questions two aspects of the Project: the 200-foot project area that extends outward from the roadway's centerline, and the one and a half height modifier for determining which trees are potentially capable of **[**22]** striking the road. While we can question some of the assumptions and analyses provided by the Forest Service, the record shows a sufficient basis for the agency's decisions.

In his declaration, Anthony Saba, a forester and silviculturist for the Forest Service, stated that the 200-foot boundary "was intended to capture the heights of most of the hazard trees that had the potential to reach the roadways within this Project area based on an estimated tree height average of approximately 100 feet." Mr. Saba also noted that trees in the Project area vary between 60 and 185 feet in height. Thus, if trees exist within the Project area up to 185 feet in height, then they may threaten a road that has a centerline at maximum 200-feet away from such trees and thus the 200-foot boundary is reasonable.

The Forest Service's reliance on the 1.5 tree height distance modifier poses a more difficult question. The majority states that it has "no doubt that felling a dangerous dead or dying tree right next to the road comes within the scope of the 'repair and maintenance' CE [categorical exclusion]. But the Project allows the felling of many more trees than that." Maj. Op. at 11. To prove this, the majority **[**23]** notes that a 100-foot-tall tree that meets the other criteria is eligible for removal if it is within 150 feet of the road. They hypothesize that this tree does not threaten the road system because even if it fell perpendicular to the road, its tip would still land 50 feet away. So, the majority argues, the repair and maintenance categorical exclusion does not apply.

The legitimacy of the tree height modifier thus becomes a paramount issue in this case. If the agency reasonably concluded that the modifier accurately reflects the potential damage area when a tree falls, then the "repair and maintenance" categorical exclusion would presumably apply. In other words, if the majority's hypothetical 100-foot tree that sits 150 feet from the road poses an actual risk to the road system, then the repair and maintenance categorical exclusion would cover the felling of that tree.

The majority concludes, however, that the modifier is not legitimate because the hypothetical 100-foot tree would extend only 100 feet on the ground once it fell, putting it well away from the road. But the agency provided a reasonable and plausible — though not indisputable — basis for the modifier. Namely, decayed trees **[**24]** can sling detritus like branches and limbs **[*995]** when falling; the tree's final resting place on the ground does not reflect a one-to-one relationship with its height. The Forest Service's Hazard Tree Guidelines note: "When a tree or tree part fails, it may strike other trees or debris on the ground and fling material a considerable distance." These conditions can be exacerbated by other factors, too, like wind, breakage forces, and slope. I agree with the majority that there are a limited number of angles that a tree might fall to pose an actual threat to a public road. But we cannot know the exact direction a tree will fall until it does. While we may question whether the Forest Service's use of a 1.5 tree height modifier reflects the most accurate or efficient criterion, it is not arbitrary or capricious and we must defer to the agency's expertise in this area. *See* Save the Peaks Coal. v. USFS, 669 F.3d 1025, 1035 (9th Cir. 2012) ("Under the APA, [an] agency's decision may be set aside *only* if it is arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law." (emphasis added) (internal citations omitted)); *see also* 5 U.S.C. § 706(2)(A).

Moreover, the record convinces me — as it did the district court, which believed the Project "impos[es] a **[**25]** meaningful limit against a free-for-all harvest" — that the Service does not intend to mark every eligible tree in the Project area. For example, Mr. Saba stated in his declaration that otherwise eligible trees would not be marked for removal by the Forest Service where geographic blockages (like rock outcroppings) would prevent the trees from striking a road. He stated that "[t]ree marking crews are trained to account for these variances, and to only mark trees meeting the criteria that have an actual potential to impact Forest roadways."

While the Project may be imperfect and we may question the wisdom of some of the assumptions, I cannot say that the Forest Service's decisions were arbitrary or capricious. Nor can I say that district court abused its discretion in finding that EPIC failed to show that it was likely to succeed on the merits of their claim.

2. *Irreparable harm, the balance of equities, and the preliminary injunction being in the public's interest are closer calls than the majority recognizes*.

The district court did not abuse its discretion in finding that EPIC failed to show a likelihood of success on the merits of its claim. That alone should end our inquiry. *See* Edge, 929 F.3d at 663. **[**26]** But the remaining preliminary injunction factors are a closer call than the majority recognizes.

The majority correctly notes that ongoing harm to the environment may constitute irreparable harm, but it is not clear that Project will lead to such damage. While some portions of the Project overlap with critical habitat for spotted owls, a Forest Service biologist concluded that the Project is unlikely to adversely affect spotted owl habitat.

As for the balance of equities and whether the preliminary injunction is in the public's interest, the majority concludes that these factors favor EPIC because "EPIC seeks only the preparation of an EIS or an EA," and that "[t]he public interest is served by requiring the Forest Service to comply with the law." Maj. Op. at 15. But Ms. Carlson makes clear in her declaration that without these timber sales, the Service will be forced to close roads and recreation areas on a longterm basis. Certainly, the public has a strong interest in enjoying trips to Mendocino National Forest. The public also has an interest in protecting taxpayers' money through sound management by the Forest Service. I do not believe the majority's opinion adequately considers **[**27]** these countervailing **[*996]** concerns. *See* Weinberger v. Romero-Barcelo, 456 U.S. 305, 312, 102 S. Ct. 1798, 72 L. Ed. 2d 91 (1982) ("In exercising their sound discretion, courts of equity should pay particular regard for the public consequences in employing the extraordinary remedy of injunction."); *see also* League of Wilderness Defs./Blue Mountains Biodiversity Project v. Connaughton, 752 F.3d 755, 765 (9th Cir. 2014) ("Both the economic and environmental interests are relevant factors, and both carry weight in this analysis.").

In sum, I believe that the district court did not abuse its discretion in denying EPIC's request for a preliminary injunction, and that we must defer to the agency's actions within its expertise. I thus respectfully dissent.

End of Document

United States Department of Agriculture

Tree Risk Assessment and Hazard Tree Mitigation in the Southwestern Region

Forest Service | Southwestern Region | Forest Health TP-R3-16-37 | June 2020

Forest Service
Southwestern Region
Forest Health
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Cover photo: Dead ponderosa pine with its large diameter top broken out near a high value structure, emphasizing the importance of a tree risk assessment and hazard tree mitigation program.

Tree Risk Assessment and Hazard Tree Mitigation in the Southwestern Region

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Introduction

Sustainable recreation is a major priority in the Southwestern Region of the USDA Forest Service. Maintaining safe developed recreation sites, as well as developed sites of any type (e.g., administrative sites, informational kiosks, etc.), is a necessity in the national forests of the Region. The threat posed by hazard trees within developed sites (or danger trees along roadways) can be quite severe, and a tree risk assessment and hazard tree mitigation plan is a vital component of any recreation program.

A tree becomes hazardous when a structural defect increases the probability the tree or part of the tree will fail and cause damage to people or property. Any area with tree cover can be temporarily or permanently rendered unsafe by structural defects such as dead tops, defective/broken branches, or large mortality events. Federal agencies that manage recreation sites are legally required to mitigate these hazards and maintain safe developed areas. Developing a tree risk assessment and hazard tree mitigation program with staff trained in the identification of the most common tree defects is critical to fulfilling this obligation. This requirement is codified in Forest Service Manuals (FSM) and Forest Service Handbooks (FSH). The FSM contain legal authorities, objectives, policies, responsibilities, instructions, and guidance needed on a continuing basis by Forest Service line officers and primary staff to plan and execute assigned programs and activities, whereas FSH are the principal source of specialized guidance and instruction for carrying out the direction issued in the FSM. Some of the national guidance on tree risk management may be found in FSM 2300 and FSH 7709.59.

A tree risk assessment and hazard tree mitigation program provides a systematic method of mitigating tree hazards to decrease the likelihood that damage to people or property will occur. Evaluations should be performed by personnel trained in the identification of hazard trees and should prioritize areas by level of visitor use or other assigned value (e.g., cultural sites, high value infrastructure, etc.). High priority areas may include parking lots, walkways, visitor centers, campsites, and picnic grounds. Evaluating trees for risk involves identifying trees within striking distance of a target (e.g., a fire ring or picnic table), assessing for structural defects on those trees, associating those defects with a known pattern of failure, and assigning a relative rating for the degree of risk of that tree or part of that tree striking the identified target. A familiarity with local vegetation as well as tree defects or forest health issues common to the area will greatly improve the efficacy of tree risk assessors, as defects and tree risk issues can vary by species and geographic location.

The complex, dynamic nature of tree failures limits our ability to accurately predict where and when failures will occur. Risk of damage to person and property cannot be eliminated, but can be reduced by identifying and mitigating the most obvious tree defects in high use recreation areas. Tree risk assessment and hazard tree mitigation programs are challenged with striking a balance between increasing public safety while retaining as much of the vegetation resource as possible.

Hazard Tree Definition and Ratings

For the purposes of this guide, a hazard tree is defined as a tree that has both:

1. A structural defect that increases the probability that the whole tree or tree parts will fail and
2. A target (e.g., people, buildings, vehicles, etc.) that could be hit when the tree or its parts do fail.

Tree risk ratings in the Southwestern Region are calculated by multiplying relative risk values associated with tree defects by the target value or priority level. The various defects that can be found in the region are described in detail in the “Hazard tree defects” section of this document.

Tree Risk Assessments

Tree risk assessors should consider the size and location of a tree to determine if an in-depth inspection is warranted. Small trees that cannot cause damage to targets and trees that are too far away from a target to strike it should not be inspected. A flow chart that can help tree risk assessors move through a given site is shown in Figure 1. Trees that do warrant thorough inspection should be surveyed from top to bottom and 360° around the tree. Defects may occur in the roots, base, trunk, or in large limbs throughout the crown. A tree may look defect-free from one angle, while another angle may reveal catastrophic defects. Some agencies responsible for managing hazard trees along roadways, where they are commonly known as danger trees, may have to do rapid "windshield surveys" in these areas. Only the most obvious defects will be identified in these rapid surveys, such as dead or dying trees and severe, unnatural leans. Mitigating the most obvious defects will reduce some risk of hazard tree failures along roadways, but more thorough assessments are always recommended when possible. For roadway tree risk management, more attention could be focused on chokepoints near pullouts for overlooks or trailheads and other areas where vehicles are present in high numbers and potentially traveling at low speed. Thorough assessments are an absolute necessity in developed recreation sites and other areas with high-value targets.

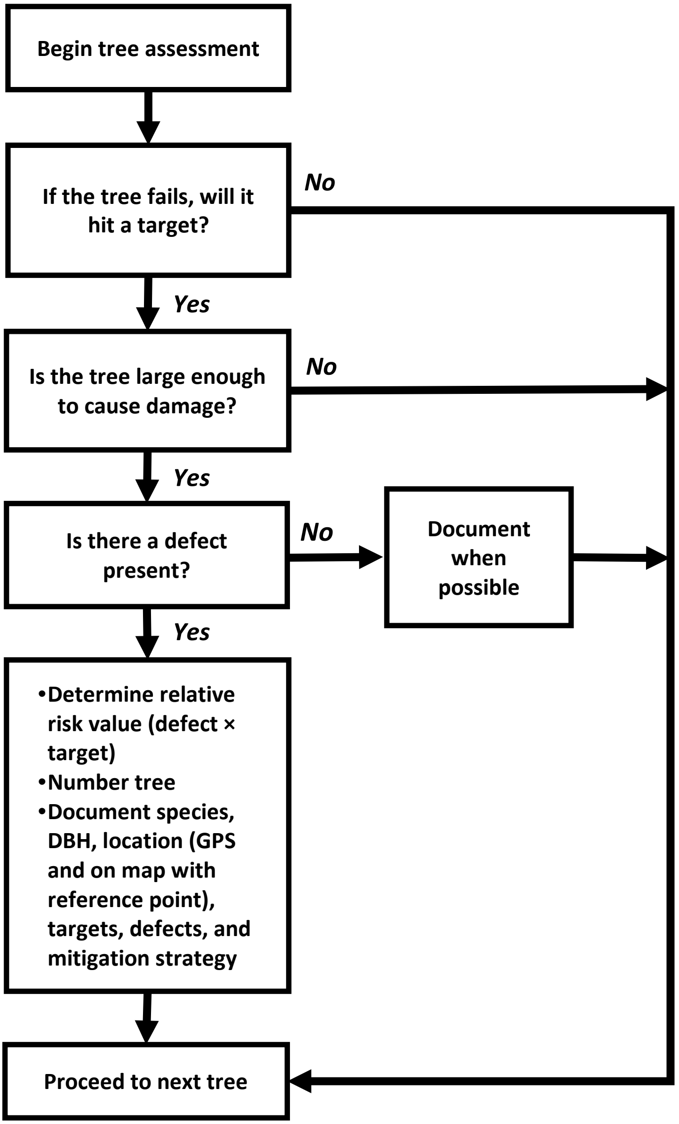

Figure 1. Flow chart to aid tree risk assessors in surveying developed recreation sites.

Potential Impact Zone

The potential impact zone (PIZ) refers to any area that could be impacted by any part of a failed tree. The graphics below display some of the many site characteristics which may influence the potential impact zone. Keep in mind, the failure of a tree can cause adjacent trees, or parts of trees, to fail (a domino effect). This can result in impacts outside the PIZ of a particular tree.

- **Flat Ground; slope and lean of tree both < 15°:** the PIZ of a tree with these characteristics can be represented by a circle around the tree in question with a radius equal to the total height of the tree, h (Figure 2).

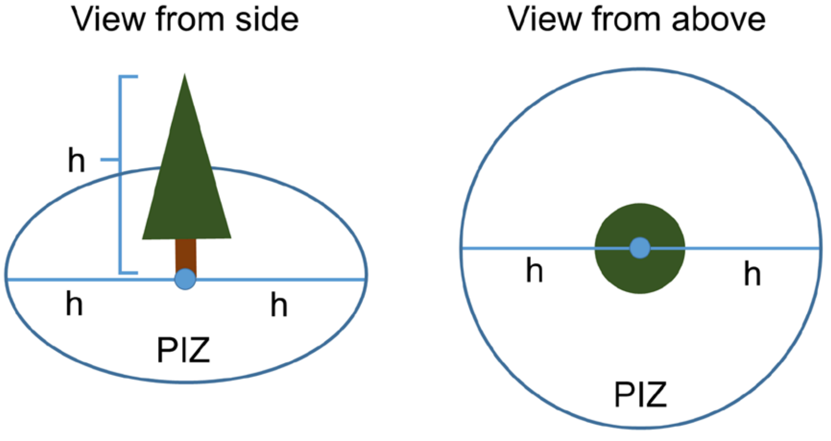

Figure 2. Potential impact zone (PIZ) for a tree with less than a 15° lean on less than a 15° slope; PIZ is represented by a circle around the tree with radius equal to tree height (h).

- **Tree on slope > 15°:** trees on slopes greater than 15° can slide downslope and may affect a larger area on this side. The PIZ will therefore need to be extended in these scenarios. There is no standard for extending the PIZ; this decision should be made by a trained tree risk assessor and extended to a distance deemed necessary to ensure public safety. Topographic features, presence of other trees, steepness of the slope, and other factors should be taken into account when determining PIZ. A PIZ of 1.5 to 2 times the height of the tree is often used for trees on moderately steep slopes (Figure 3).

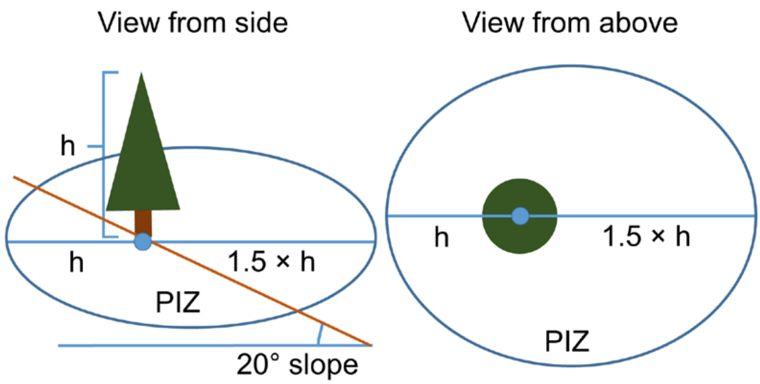

Figure 3. Potential impact zone (PIZ) for a tree on a greater than 15° slope; the PIZ is extended beyond the tree height (h) in the downslope direction.

- **Tree lean > 15°:** the majority of failures on trees with a lean > 15° occur anywhere from the direction of the lean to 90° on either side of the direction of the lean. A distance equal to the total tree height in this area (90° on either side of the lean) will comprise the PIZ in these situations. Slope as well as other trees and objects in the area will also need to be taken into account. In severe storms or windy days, trees with significant leans may experience backlash and fall in the opposite direction of the lean. This zone is generally much smaller than the PIZ in the direction of the lean (Figure 4).

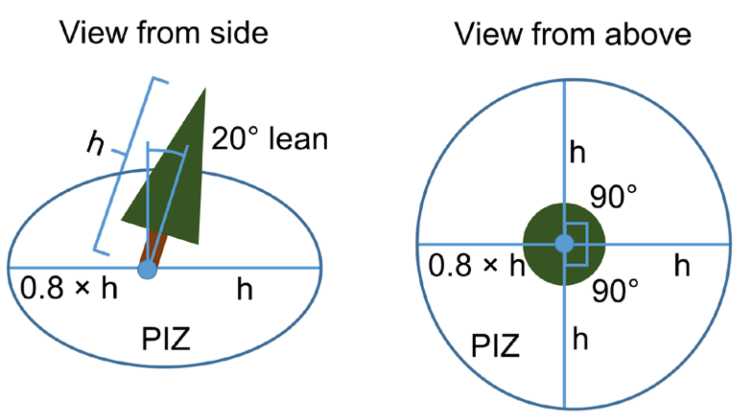

Figure 4. Potential impact zone (PIZ) for a tree with greater than a 15° lean; the PIZ is equal to at least the height of the tree (h) in the direction of the lean and within 90° of the lean in either direction. The PIZ may be reduced from h on the side opposite the lean.

One quick and easy method for determining if a given tree could potentially hit a target involves measuring angles to the top and bottom of the tree from the target in question using a clinometer, laser hypsometer, or cell phone app. If twice the angle to the top of the tree (A') minus the angle to the bottom of the tree (A) from the target is greater than or equal to 90°, the tree in question could potentially hit that target if it fails ($2 \times A' - A \geq 90°$). Examples are shown in Figure 5. It should be noted that the trees depicted in the diagram below are assumed to be on a < 15° slope. The 90° cutoff can be reduced if the assessor believes adjusting the PIZ by 1.5 × h (67° cutoff) or 2 × h (53° cutoff) is warranted to account for steeper slopes.

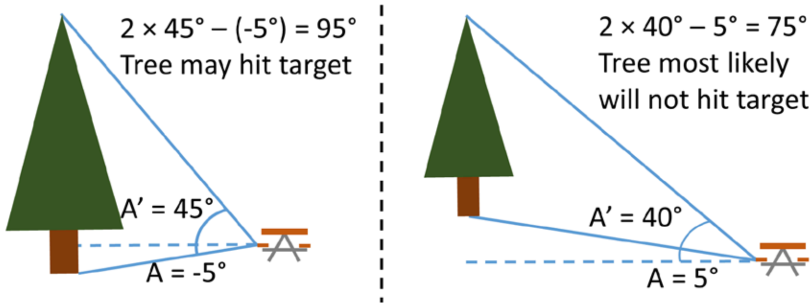

Figure 5. From a given potential target (e.g., a picnic table), it is 45° to the top of one possible hazard tree and -5° to the bottom ($2 \times 45° - (-5°) = 95°$). Because the result is greater than or equal to 90°, the tree could potentially hit the picnic table. From that same target, it is 40° to the top of another possible hazard tree and 5° to the bottom ($2 \times 40° - 5° = 75°$). Because the result is less than 90°, this tree would most likely not hit the target if it failed.

Rating Tree Risk

The tree risk rating system presented here includes two components: a target value and a defect value. These two ratings are multiplied together to give a final risk rating for the tree.

1. **Target Value (1-2):** this value represents the likelihood that there will be damage to people or property.

    1: A value of one corresponds to an area where people will not be stationary for long periods of time but rather will be moving/driving through, such as roads or trails. These areas have a lower probability of being affected by a hazard tree due to the target moving through the area of concern rather than being stationary.

2: A value of two indicates areas with higher probability of damage to people or property. This value will generally be used for campsites, picnic tables, visitor centers, parking areas, information kiosks, and any other areas in which people may congregate and be stationary for longer periods of time.

2. **Defect Value (1-3):** this value represents the likelihood that a tree or part of a tree will fail and cause damage to the target.

   1: A value of one represents a minor defect with a lower probability of failure, indicating that the tree should be assessed annually to monitor any progression of the defect. Generally, no action will be taken to mitigate a defect with a value of one.

   2: A value of two represents a defect that has a moderate failure potential and does not represent an imminent failure. These defects will need to be monitored closely at least annually and possibly removed depending on the level of acceptable risk, the value of the tree, and the value of the target.

   3: A value of three represents a high hazard defect with imminent failure potential. Targets with a value of two that can be damaged by trees with a defect value of three should be prioritized for mitigation.

After a value has been assigned to the target and the defect, the two values are multiplied together for a final risk rating. The higher this value the higher the risk of resource damage or injury from a tree or tree part failure. In developed areas with high priority targets, trees will typically have risk ratings of 2, 4, or 6. A rating of 6 indicates a high risk hazard that should be mitigated as soon as practicable. A value of 4 indicates a moderate hazard, and a value of 2 indicates a low hazard. In some instances, multiple defects may interact and increase the risk of failure. Some examples of interacting defects could include:

- Codominant stems with included bark and associated decay or cracking
- Leaning trees with root rot or other root damage
- Leaning trees with decay or cracking
- Large diameter, overextended branches with decay or cracking
- Large branch unions with decay or cracking

It may be prudent, depending on the value of the trees present, to optimize the use of crews when they are on site and mitigate as many of the hazard trees as possible, including the trees with lower risk ratings that would otherwise be monitored (trees that were rated a 4 or less). It should be noted that trees with lower value/occupancy targets like roadways will have a maximum risk rating of 3; hazards posed by these trees should nevertheless be mitigated. An acceptable level of risk should be communicated by the line officer and ideally would be included in the unit's vegetation management plan for developed sites. Line officer direction and these management plans will dictate which hazards are deemed acceptable. Guidance on developing vegetation management plans is provided in Region 2's Vegetation Management Planning Guide (USDA Forest Service 2002). Region 1 also provides a guide and template that can be adapted for developed sites in the Southwest (https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5334504.pdf).

The mitigation of tree hazards, or danger trees, along roadways is an important component of a comprehensive tree risk program (USDA Forest Service 2016). Land management adjacent to major roadways can be convoluted, with various land management agencies involved, including state, federal, and local governments. It is important to know who is responsible for mitigating the hazards along roads. While trees along roadways may only have risk ratings of 1, 2, or 3, they still should be managed to reduce risk and limit failures. Inspection of a road system is often hampered by the number of miles that need to be covered. An example of a decision tree for prioritizing inspections for roadways can be found below (Figure 6).

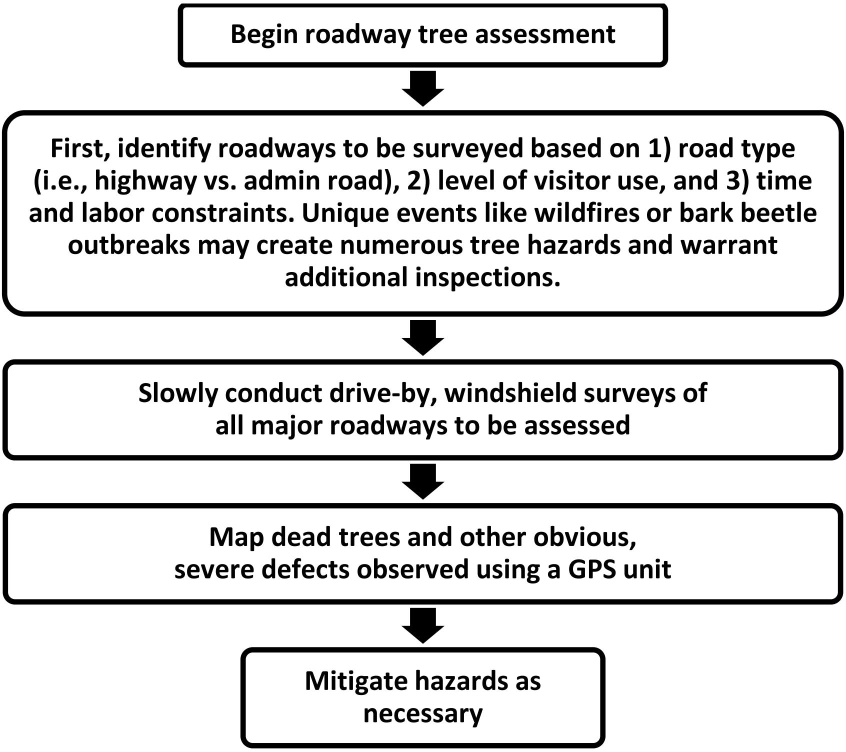

Figure 6. Flow chart to aid tree risk assessors in surveying along roadways.

Assigning a relative hazard value depends on several interacting factors, including tree species, presence of insects/diseases, stand age, past disturbances, and site or environmental conditions. Predicting tree failures is therefore not an exact science, but there are certain characteristics we can look for to reduce the probability of a hazard tree causing harm to person or property. Some of the most important characteristics to look for include:

1. Is the tree alive or dead?
2. Presence of dead or dead hanging limbs in the crown.
3. The lean of the tree. Is the lean natural or was it caused by damage?
4. Presence of significant insect or disease activity.
5. Presence of mechanical damage to bole or roots of the tree.

Inspection Tools

Many tools are important when conducting tree risk assessments. Tools needed during tree risk assessments include:

- Inspection and failure report forms
- Site maps
- GPS unit
- Compass
- Diameter tape to measure diameter at breast height (DBH)
- Measuring tape (100’ or so)
- Clinometer or other tool to measure tree height
- Tree tags and nails (aluminum)
- Camera
- Binoculars
- Chaining pins
- Rubber/plastic mallet
- Cordless drill
- Earplugs
- Increment borer
- Tablet or smartphone

Binoculars can be helpful for inspecting potential hazard trees for defects of large branches in the crown. Chaining pins or similar tools can be used to investigate the inside of decay cavities and determine the extent of decayed wood.

Mallets (rubber or plastic) can be used for sounding trees potentially hollowed by stem decay. The sound produced by a hollow or decayed tree will differ from the sound produced when striking solid wood. Different tree species have different densities of wood and produce varying sounds, so this technique requires skill and experience. Practicing with an experienced tree risk assessor is necessary.

When hollows are detected by sounding, or if obvious decay is present in association with a fruiting body, cavity, or wound; it may be necessary to measure the amount of sound wood present in that tree part. Increment borers or handheld, battery-powered drills with long 1/8” bits can be used for measuring percent sound wood. Using an increment borer, the extent of decay can be determined visually from the cores. Using a drill, constant power and pressure should be applied to a trunk or large limb with suspected decay until the drill reaches about halfway through the diameter or until a reduction in resistance occurs, whichever occurs first. If a reduction in resistance occurs, drilling should immediately stop, and the drill bit should be marked at the edge of the bark where the bit enters the tree. The length of the drill bit from the tip to the point on the bit where resistance decreased (minus an estimate of bark thickness) will represent the radius of sound wood. An earplug can be used as a marker and will stay in place where drilling stopped once the bit is removed. Trees that have significant decay should be measured in at least two more locations around the circumference of the trunk or limb to determine uniformity of the decay and an average sound wood thickness.

An alternative drilling method is to calculate the amount of sound wood necessary for the particular tree part you are inspecting and set a stopper (earplug, marker, tape, etc.) on the drill bit corresponding to that length, taking into account bark thickness. Then drill into the tree using constant steady pressure until the stopper is reached. With this method, it can be confirmed that the tree meets sound shell limits without drilling into decay columns.

Maintaining records of tree risk inspections is vital. Many of these items can be consolidated with the use of electronic data collection and storage tools. Federal tree risk assessors with agency access to ArcGIS Online may use the app Survey123, which can be downloaded on a personal or government phone or tablet. Each National Forest or National Park Service (NPS) unit can contact Region 3 Forest Health Protection for an Excel file template they can use to generate a Survey123 survey based on the tree risk assessment form presented in this guide. The form collects date, species, DBH, height, and location data for each tree surveyed, as well as information on targets and defects (including automatic risk rating calculation). Additionally, up to five photos can be stored in association with each survey entry, allowing for the assessor to include photos of the general area where the tree being surveyed is found, along with overview photos and detailed images of any major defects. Recommended mitigation actions can be stored in the system as well. All data can then be uploaded to a cloud-based storage service for each respective Forest or NPS unit.

Documentation

Proper documentation is a critical component of the tree risk assessment process. Maintaining documentation of tree risk assessments as well as subsequent hazard tree mitigation provides evidence that these tasks were conducted. It is of the utmost importance to have these records available in the event of a hazard tree incident and subsequent litigation. These records are a vital tool for personnel who will be performing future surveys, providing locations of trees and defect information, aiding in planning, and helping to prioritize future surveys. This information can also be used to inform long-term vegetation management plans, as information on insects, disease, and other defects can help guide which species will be preferred in the future. Proper documentation includes:

- Date of inspection
- Name of tree risk assessor
- Tree species
- DBH
- Distance/azimuth to permanent reference point or GPS coordinates and a photo of the tree
- Identification of target, potentially including a photo
- Description of defects present along with photos of these defects
- Risk rating and mitigation strategy
- Date of mitigation
- Any other pertinent information

These data can be collected using whichever collection form fits with your agency priorities. This guide will focus on the Region 3 Tree Risk Assessment Form found in Appendix 2 and the associated Excel-based survey in Survey123 that can be provided by Region 3 Forest Health Protection. Tree risk assessment and hazard tree mitigation data should be stored based on agency record retention guidelines in paper and/or electronic form. Documenting information for trees with no defects is encouraged when possible to give a complete picture of each site.

Prioritizing Areas for Intensity of Inspection

Areas should be prioritized based on their respective level of development or risk level (e.g., increased risk following tree damage or mortality event). This can include prioritizing areas surrounding a visitor center over a minimally used, undeveloped campground. It can also include breaking up a given site into priority zones based on relative risk (Figure 7). For example, a campground can be considered to have high risk areas (e.g., tent pads, bathrooms, and other facilities) as well as more moderate or even low risk areas (e.g., roadways and trails between sites). A more liberal tree risk policy may be maintained for the lower risk areas. Higher risk zones, however, where tree failures could cause major property damage, personal injury, or even death, should be managed with a more conservative tree risk policy.

In-depth inspections may not be possible for every site every year. As such, inspections may be structured so that each site is initially thoroughly inspected with in-depth, 360° surveys with follow up, walkthrough inspections occurring annually thereafter. Additional thorough inspections should occur on a semi-regular basis but at least every five years or following storms, insect or disease outbreaks, etc. Each unit must dictate their own schedule based on needs. The schedule should be defined in the unit's tree risk assessment program and should be followed. An example is provided below:

Year 1:	360° full inspection of all moderate and high risk areas
Year 2:	Walkthrough survey
Year 3:	360° full inspection of all high risk areas
Year 4:	Walkthrough survey
Year 5:	Walkthrough survey
Year 6:	360° full inspection of all moderate and high risk areas

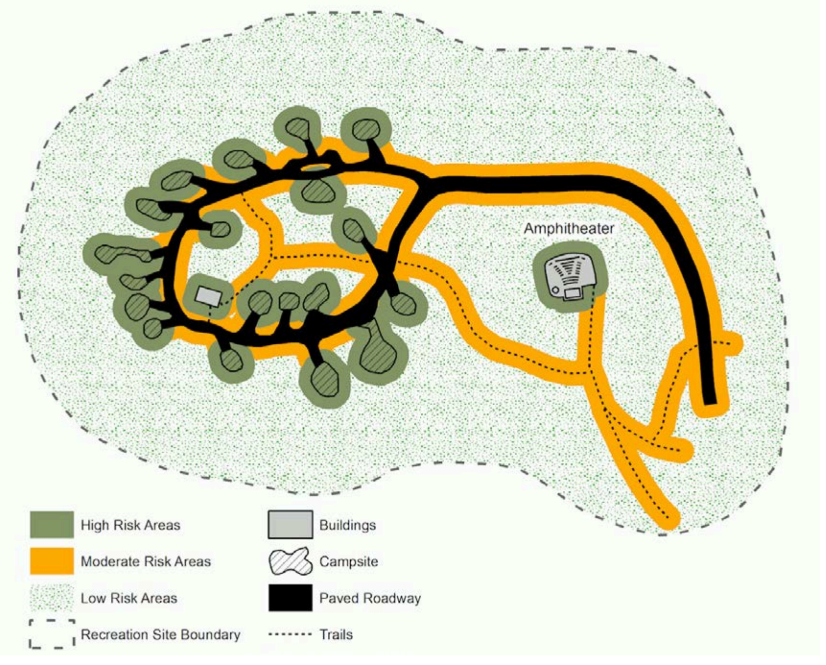

Figure 7. Recreation areas should be divided into hazard risk zones which determine the intensity of inspection.

Timing of Tree Risk Inspections

Developed recreation sites should be assessed at least on an annual basis. The timing of each tree risk assessment should be prior to the season of highest use. For most recreation areas this will be in the early spring before sites open for the summer season. New hazards, such as dead hanging branches and broken tops, may develop over the winter due to severe storms and heavy snow loads. In addition, mortality and defects that developed and progressed through the last growing season can be assessed, documented, and mitigated if necessary. Recreation areas that see peak use in the winter should be assessed in the late summer prior to opening. Sites with a large component of deciduous trees should be assessed after bud burst or before leaves drop in the fall, which can help with identifying dead trees or tops and large dead limbs (Figure 8).

Figure 8. Dead tree missed during tree risk assessments conducted during dormant season before bud burst.

Ideally, hazard trees can be assessed and high hazards mitigated prior to the opening of the site or the season of highest use. In addition to surveying prior to the peak season, it is also recommended that ad hoc surveys be performed as needed, for example following severe weather events midway through the field season or post-wildfire, before reopening sites. Events like these can create severe hazards quickly and warrant a thorough reassessment of the recreation area.

Post-Fire Marking Guidelines

Wildfires that burn through developed recreation areas and along major roadways present unique challenges to managers. It is important to understand characteristics that best serve as predictors of post-fire mortality and determine the level of risk your forest or district is willing to accept, developing thresholds accordingly. For example, one district may choose to cut a tree that has an 85% probability of mortality, whereas another district, willing to accept less risk, may choose a threshold of 60%. The most important and easily assessed predictors of tree mortality following wildfire are crown scorch, crown consumption, and crown kill. Crown kill refers to the percent of crown in which all buds are killed. Crown scorch is defined as the percent of crown that was scorched but not consumed by the fire; needles will still be visible, attached to the tree, and likely a red/brown color. Bud survival depends on species, and crown scorch may represent crown kill for species with buds less adapted to high heat. For example, ponderosa pine buds are relatively large and can tolerate higher levels of scorch than species with smaller buds like Douglas-fir. Crown consumption is defined as the percent of the crown that is directly consumed by the fire; needles are consumed, and buds are killed. Crown consumption can be assumed to represent crown kill in most situations. Crown kill is very difficult to assess in the same season or year as the fire and will be most accurate in the season following the fire as the flush of new green growth (live buds) will be easy to identify in fire-affected trees.

In the Southwest, most studies related to post-fire mortality have focused on ponderosa pine, which is among the most fire adapted trees of the region. These metrics therefore represent the upper limits of tolerable fire damage that trees in the Southwestern Region can survive. Metrics are presented below for ponderosa pine and Douglas-fir as examples of how crown scorch and crown consumption are used to estimate probability of mortality. In addition to directly killing trees, fire can also predispose trees to bark beetles. Bark beetle activity may increase for many years following fires and may affect trees not significantly impacted by the fire itself. Fire-affected areas should be monitored closely for many years following fire. A thorough review of fire marking is beyond the scope of this guide. Please refer to Hood et al. (2008 and 2018), Hood and Lutes (2017), and Fowler et al. (2010) for in-depth descriptions of this process.

The criteria below can be used for ponderosa pine (Fowler et al. 2010):

1. If no crown consumption is present, crown scorch affecting greater than 85% of the crown indicates 85-90% probability of mortality.
2. Crown consumption greater than 40% indicates 85-90% probability of mortality.
3. Crown consumption between 5 and 40% coupled with crown scorch > 50% indicates greater than 50% probability of mortality.

The criteria below can be used for Douglas-fir (Hood et al. 2008):

1. Crown scorch or kill of 65% indicates 50% probability of mortality.
2. Crown scorch of 80% indicates 80% probability of mortality.

In severe fires, it is possible for trees to suffer no visual crown damage, but still suffer mortality from cambial death due to high temperatures at the base of the tree, particularly where duff and litter have built up over many years. Large roots and whole root systems can also be killed and sometimes consumed by fires (Figure 9), creating unstable trees which can pose high hazards, especially when roots on the uphill side of trees are lost. Fire damage may also burn heartwood, reducing the amount of structurally sound wood, and may burn conks or other signs of significant decay. Assessing bark char or cambium kill directly can assist in the identification of trees likely to die post-fire.

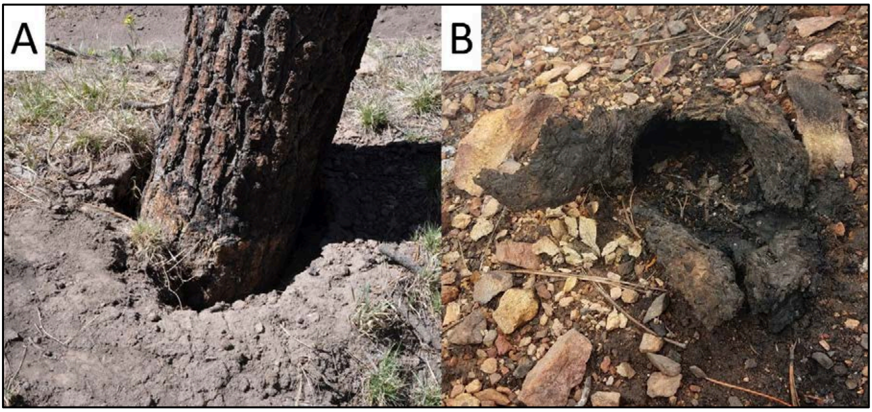

Figure 9. Ponderosa pine roots damaged by fire (A) and completely excavated by a severe fire (B).

Bole char can be divided into three categories, each corresponding to a probability of mortality:

> **Light bole char**: Light burning with many areas displaying no sign of burning. Bark furls and pattern easily distinguished. Indicates affected tree has a low probability of mortality.
>
> **Moderate bole char:** All bark blackened with no areas left unburnt. Bark features are still distinguishable. Thin barked species such as five needle pines and true firs may suffer mortality at this level. Direct sampling of cambium is required to assess mortality of trees with this level of bole char.
>
> **Severe or deep bole char**: All bark blackened; bark features no longer distinguishable. Assume cambium is dead.

It is important to assess cambium kill in trees with moderate bole char. Divide the bole into four quadrants and remove the bark from a small area in each quadrant to see the cambium. Samples should be taken within 3''of the ground and should be as small as possible to minimize injury to the tree. Live cambium will be light in color, moist, and pliable. Dead cambium will be darker, resinous, and much less pliable. Bark may be easier to remove when the cambium is dead. Most trees suffering 25% (one quadrant) or less cambium kill will survive, while trees suffering 75% or greater (3 quadrants) cambium kill have a high probability of mortality.

Hazard Tree Defects

Defects in trees are a natural part of forest ecosystems. They may provide food and shelter for various organisms in some cases. Defects that seriously weaken trees are considered hazardous if the tree or its parts can strike areas where people congregate or investments in facilities have been made, such as in campgrounds or parking areas. In these cases, tree risk takes priority over wildlife or other resource considerations. The following summarizes some major defects occurring in trees of the Southwestern Region.

Dead Trees

Dead trees receive the highest defect value of 3 because they represent imminent hazards. Decay processes degrade the structural integrity of recently killed trees quickly. In bark beetle- or drought-killed trees, the process starts just under the bark and progresses rather uniformly toward the pith. Most activity during the first year is from blue stain fungi and incipient decay with little structural degradation. By the end of the second year, degradation of sapwood can be complete depending on its thickness, tree species, and tree size. By the end of the third year, virtually no sapwood is sound, especially in smaller trees and the tops of larger trees. Outer heartwood will also have appreciable deterioration in some trees. Decay and failure can progress much more rapidly, sometimes within one year of death, if the tree is killed directly by fire or root disease. The primary agents causing deterioration are fungi and insects, with a succession of types and species changing from year to year until no sound wood remains. Deterioration occurs most rapidly in the butt portion and root system where moist conditions favor decay. Recently killed conifers without root rot may remain in a structurally sound condition for up to 3 years, but most do not. Dead hardwoods begin to lose branches earlier than conifers and pose a greater hazard. Large trees will take longer to decay and in many cases will lose their tops prior to failing at the base (Figure 10). If a dead tree is in a high hazard zone, it should be removed as soon as practicable, or other mitigating actions must be taken.

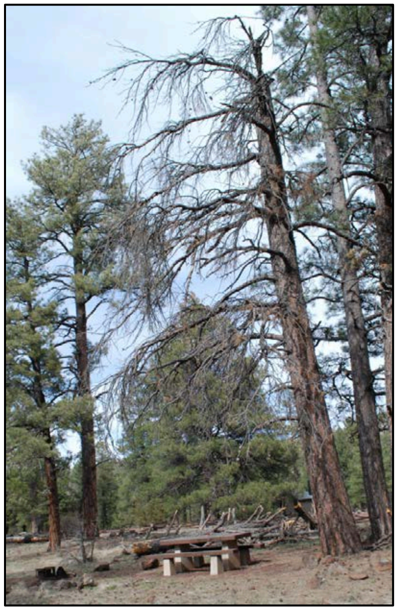

Figure 10. Failed top broken out of a ponderosa pine snag near high value picnic table and fire ring targets.

Root Injuries

Up to 75% of all tree failures are root-related (Figure 11). The majority of failures occur when winds exceed 50 mph, but root system failures may occur under any wind conditions if roots are sufficiently weakened. Areas prone to root injuries include:

- **Edges** – trees bordering natural areas, roads, driveways, and parking areas are less protected and may have experienced root damage during land clearing.
- **High traffic areas** – trees in high traffic areas are prone to soil compaction, root wounding, and root decay.
- **Wet sites** – trees growing on wet sites generally have shallow root systems. Trees on sites that have been altered suddenly by grade changes, resulting in poor drainage, and those in areas that receive excess irrigation are more likely to have root rot.
- **Areas with previously documented root disease** – biotic diseases that weaken the root structure; these will be discussed in more detail in the "Root Disease" section of this document.

Figure 11. Failed tree primarily due to a shallow root system.

Leaning Trees

Not all leaning trees are hazardous. For example, trees that lean naturally are reinforced by corrected, or compensatory, growth, often after the tree has grown into a canopy gap (Figure 12). Trees that lean because of damaged roots, however, can be very hazardous. These unnaturally leaning trees will not have compensatory growth (Figure 13). Root systems can be loosened and/or damaged from outside forces such as soil erosion, floods, heavy winds, root disease, or nearby trees falling. Look for soil mounding, root uplift, or cracking of soil at the base of the tree on the side opposite the lean. These are indicators that failure is already occurring. Unnaturally leaning trees should be removed as soon as possible or otherwise mitigated. The greater the lean of damaged trees, the greater the probability of failure during wind gusts or snow loads. Measuring the angle of a leaning tree with a tool such as a protractor from a designated spot annually can help to assess the safety of a valuable leaning tree. If the angle of the lean changes, the tree represents a high hazard. Although leaning trees may have aesthetic value, corrective action must be taken if visitor safety is threatened or recreational structures may be damaged. This can include closure of sites threatened by the leaning tree if removal cannot be done immediately or is not a mitigating action that can be considered.

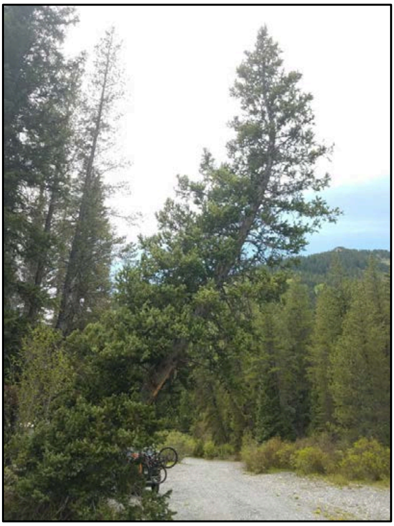

Figure 12. Naturally leaning tree with corrected or compensatory growth after the tree had grown into a canopy gap provided by a bike path.

Figure 13. Unnaturally leaning tree with no corrected growth; note the soil mounding and cracking on the side opposite the lean.

Height-to-Diameter Ratio

One structural issue that should be considered is an undesirable height-to-diameter ratio. Height-to-diameter ratios (H:D) represent an index of slenderness. Trees with a high H:D (tall and skinny) are more prone to break due to heavy snow loads and/or high winds. Trees with high H:D that have large brooms due to dwarf mistletoe or other diseases will pose an even higher risk of failing because of these additional defects. Trees with high H:D will most often be encountered in densely overstocked stands. In developed recreation sites, these types of trees could become an issue after thinning or other work exposes these “noodle” trees to increased wind and reduced support from neighboring trees. To estimate the H:D, measure the height of the tree and the DBH, both in feet. Conversion of DBH to feet from inches will likely be necessary. Then divide the height (in ft) by the DBH (in ft) to obtain the H:D. Trees with an H:D from 60:1-80:1 represent a moderate hazard that may warrant removal if additional compounding defects are present, while trees with H:D greater than 80:1 represent high hazards.

Dead Tops / Branches and Other Crown Architectural Issues

Dead tops are potentially dangerous on all hardwoods (Figure 14) and most conifers (Figure 15), especially true fir and spruce. Dead tops should be mitigated as soon as possible in hardwoods. Dead tops in conifers may not become a serious hazard for more than a year, providing the manager with some leeway before taking corrective action. Removing the top is often only a temporary fix because stubs left from topping generally decay. Also, sprouts (branches) from topping cuts are more prone to breakage due to their weak attachment.

Dead limbs may also be hazardous and require pruning (Figure 16). The following rule of thumb will help in deciding whether a dead limb should be pruned, provided it could fall on a target:

1. Prune conifers if the limb has defects such as decay or cracks or is greater than 3” in diameter and 6’ in length and has a high probability of hitting a target.
2. Prune hardwoods if the limb size exceeds 2” in diameter and 4’ in length and has high probability of hitting a target.

Figure 14. Dead hardwood tops not initially documented due to assessments being conducted during dormant season.

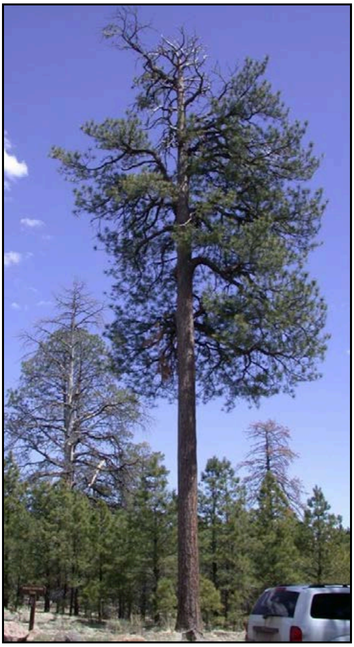

Figure 15. Dead-topped ponderosa pine with potential target in nearby parked vehicles.

Figure 16. Dead branches on a ponderosa pine.

Branches that have been dead for several years usually form callus tissue around the branch stub. These branches should be severed at the point where the dead branch and callus meet. Do not cut into callus tissue, as this will enlarge the wound and increase the chance of decay. The callus area can be found by removing loose bark. More details on proper pruning technique can be found in the “How to Prune Trees” guide listed in the references of this document (Bedker et al. 2012).

Other architectural issues that may require pruning include overextended branches and volunteer tops. Overextended branches, those that extend past the majority of the canopy or are excessively long and have poor taper, can be a serious issue in riparian hardwoods like Arizona sycamore and cottonwood. When numerous vertical branches arise from an overextended horizontal branch, sometimes called “harp trees”, great strain is put on the branch’s union to the trunk. These unions should be inspected thoroughly for cracking or decay. Healthy volunteer tops that emerge as a result of the loss of a leader, although not immediately hazardous, may develop a fracture point where the new leader takes off. Top breakage could occur years later from wind, heavy ice, or snowstorms, posing a hazard primarily in areas of year-round occupancy or where people gather for winter sports.

Trunk Injuries and Defects

The trunk must support the weight of the entire crown, and any structural injury in the trunk increases the chance for failure. Trunk defects include forked trees, which are also known as codominant stems. Single stems represent stronger architecture than forked stems. Codominant stems with a U-shaped union are less likely to have “included bark,” so in the absence of cracking or obvious decay, this is considered to be a minor defect (Figure 17). V-shaped unions present a moderate hazard as they often have “included bark”, visible as a widened ridge between the two stems (Figure 18). In these situations, each stem pushes against the other with increasing pressure over time as they grow in girth, eventually leading to failure of one (Figure 19) or both of the stems. Trees should be removed or otherwise mitigated if cracking is present or signs of decay occur at the union or after failure of one of the stems. Failure of one stem leaves behind a major wound for stem decay fungi to enter and also drastically alters the structural integrity of the remaining crown.

Figure 17. U-shaped codominant stem union with no included bark.

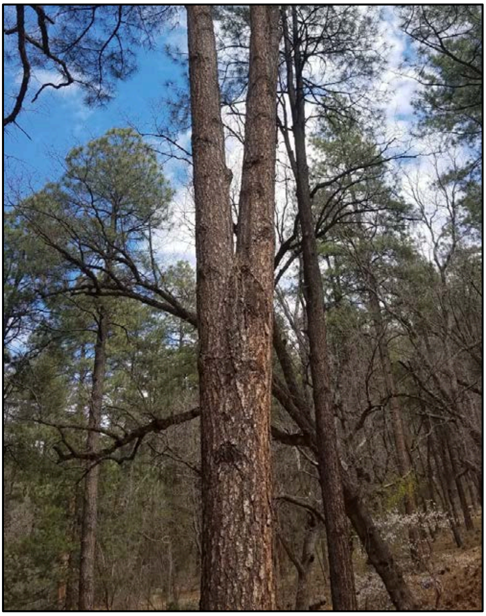

Figure 18. V-shaped codominant stem union with included bark.

Figure 19. Codominant stems with included bark eventually fail, leaving behind a major wound and structurally compromised crown.

Trunk wounds of any type, although they may not be structurally compromising, may serve as an entry point for decay fungi that reduce the volume of sound wood and increase the probability of stem breakage. Trunk wounds may be caused by animal damage, fire scars, lightning, canker diseases, mechanical injury, and other agents. Some of the more common trunk injuries and entry points for stem decay fungi are discussed in more detail below.

Cankers

Cankers are characterized by localized dead areas on the bark of stems and branches caused by fungal and bacterial pathogens. Wood beneath cankers may be decayed. Many cankers occur on aspen because of their easily wounded and colonized living bark, but most do not represent immediate hazard tree issues and should primarily be considered as a possible entry point for decay pathogens. Their severity in a tree risk assessment context therefore depends on the proportion of the stem circumference that is occupied by the canker. One exception, however, is the disease sooty bark canker, caused by the fungal pathogen *Encoelia pruinosa*. The disease is easily recognizable by alternating dark and light patches of bark (Figure 20) which has led to an alternative common name, barber pole canker. The disease may also be identified by the cup-like fruiting bodies found on killed bark (Figure 21). Aspen infected by this pathogen may be considered dead trees during tree risk surveys and mitigated as if the tree had already succumbed, as this canker is lethal. It is important to note that canker pathogens are generally considered secondary organisms which impact stressed host trees, although this is not always the case.

Figure 20. Sooty bark canker of aspen.

Figure 21. Cup-like fruiting bodies associated with sooty bark canker.

Lightning Scars

Trees standing alone, especially tall trees, are more prone to lightning strikes. Lightning can kill trees immediately, create wounds that may become entry points for decay, or cause structural damage to xylem that may lead to failure (Figure 22). Lightning strikes also attract bark beetles which may contribute to top-kill or mortality. Lightning scars can be shallow or wide cracks that extend into the bark. Depending on when the strike occurred, callus tissue may have formed on either side of the blown-out bark strip. Probability of failure increases with size and extent of the crack. Old lightning scars may indicate the presence of decay. Trees with multiple strikes are more likely to have internal cracking and decay. Large trees with lightning scars and major targets should be monitored closely over time for stem decay issues or other structural problems.

Figure 22. Failed ponderosa pine with lightning scar extending to its base, the likely source of the stem decay that ultimately compromised the tree.

Cracks

Radial separations in the wood and bark may be associated with extensive internal decay, minor wounds, rapid growth rate, or sudden temperature changes. Many cracks are eventually sealed over by callus tissue. However, they can still serve as entry points to decay prior to healing. Cracks are considered severe defects if they shear through the main stem or large limbs or if they occur against the grain of the wood. This indicates that failure is already occurring and represents a severe hazard. Similarly, cracks associated with codominant stems should be considered severe hazards. “Ram’s horn” cracks occur where healing is initiated from either side of a large wound, but the wound is never able to be fully sealed, causing callus tissue to roll inward (Figure 23). These can hide large areas of decay. Ram’s horns are common in Arizona sycamore.

Figure 23. Ram's horn crack from an Arizona sycamore.

Broom-Inducing Pathogens

Dwarf mistletoes cause growth loss, vigor reduction, and mortality. These parasitic plants, along with a number of fungal pathogens, can induce witches' brooms, proliferations of branches originating from a single point (Figure 24), as well as swellings on branches. These defects are generally not a serious structural hazard except when subjected to heavy snow loads. Infected living trees are not inherently hazardous, but mortality is more common in older mature trees. Additionally, dead brooms on living trees can provide opportunities for stem decay fungi to enter these trees and initiate heart rot. Large brooms may also increase the impacts of wind on a tree, increasing the chances it will fail in storms.

Figure 24. Dead ponderosa pine witches' brooms induced by southwestern dwarf mistletoe.

Insect Damage

The risk of insect damage contributing to the potential of hazard trees can range from inconsequential to extreme. Light damage, such as small amounts of defoliation, will likely have little impact on tree health/integrity. Bark beetle attacks, on the other hand, can lead to an immediate hazard. Furthermore, even a small number of bark beetle attacks may indicate the presence of other problems, particularly root rot. Lightning strikes or other abiotic conditions such as drought or large scale blowdown events can lead to bark beetle outbreaks that cause widespread tree mortality within developed sites and an increase in hazard tree issues (Figure 25). Actions such as the removal of infested trees prior to beetle emergence and the removal, debarking, or burning of fresh blowdown material will aid in reducing the impacts from bark beetles. It is recommended that treatments in conifers, including pruning, which do not immediately remove material from the site be restricted to July through January, as this will also help to reduce the likelihood of beetle outbreaks. Chipping will also reduce available host material; however, as stated previously, if chips are not immediately removed from the site, guidelines should be followed with regard to timing (July-January) and placement (in the open, away from the base of trees), as the volatiles released from chips may attract beetles that subsequently attack standing trees.

Figure 25. Ponderosa pine mortality pocket due to localized bark beetle outbreak.

Additionally, carpenter ants often enter conifers or hardwoods that are already suffering from butt rot and expedite the eventual failure of the tree by mining the interior (Figure 26). Check trees for insect frass near the base of the tree (Figure 27). The presence of carpenter ants indicates that stem decay is extensive, and tree removal or other mitigating action is likely warranted.

Figure 26. Carpenter ant damage (Steven Katovich, Bugwood.org).

Figure 27. Carpenter ant frass at the base of an infested tree (Dave Powell, USDA Forest Service (Retired), Bugwood.org).

Stem Decays

Stem decay is caused by many species of fungi. Heartwood decay fungi are often active while trees are living, while fungi that decay sapwood are generally active after a tree or tree part has been killed. Some fungi can begin as heart rots and move into the sapwood and cambium, girdling and killing the host trees. Most stem rots decay the heartwood, which is nonliving tissue functioning as structural support for the tree. Therefore, many stem rots do little to affect flow of nutrients and water and will cause no outward symptoms on the affected tree, the lack of which can make identifying trees with heart rot rather difficult. Decay of heartwood or sapwood increases the probability of stem breakage and tree failure, and identifying affected trees is vital. Stem rots are most prevalent in large older trees, which are also highly desirable to the public. Recreation sites with large old trees should be monitored carefully for signs and symptoms of stem rots. The two most common types of wood decay encountered by tree risk assessors are brown rots and white rots. Brown rot fungi preferentially degrade cellulose and leave behind lignin, giving the remaining material a brown color and a cubical and crumbly texture (Figure 28). White rot fungi preferentially degrade lignin leaving behind much of the cellulose, and remaining material appears white in color with a spongy, stringy, and/or fibrous texture (Figure 29). Brown rots cause strength loss much faster than white rot fungi, often before any symptoms are present.

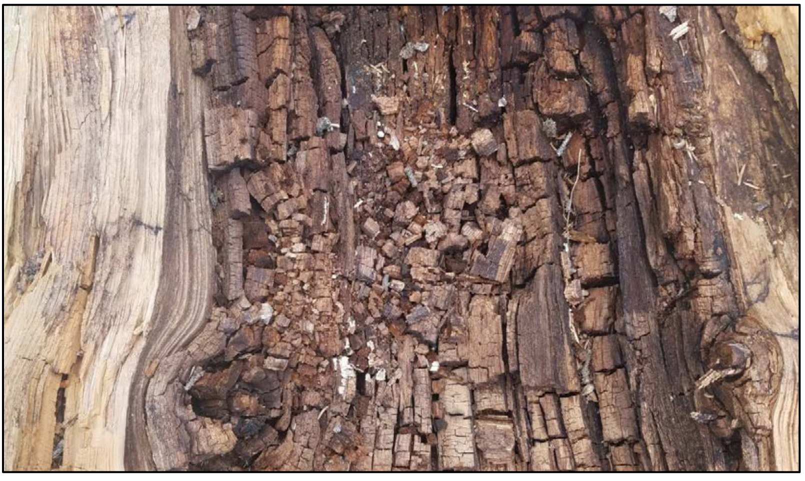

Figure 28. Cubical, crumbly brown rot.

Figure 29. Spongy, stringy, and fibrous white pocket rot.

Stem rots gain access to heartwood or sapwood through injuries, such a lightning scars and dead branch stubs, or they may be vectored by insects. Stem rots can be identified by the presence of conks or punk knots, both of which are signs of the decay. However, there will frequently be no obvious sign of decay, no fruiting body or conk, and the host will show no symptoms of infection. Sap rots will decay sapwood of host trees and generally be associated with stressed or recently dead trees. Decay due to sap rot affects structural integrity far more seriously than heart rots (Figure 30). It is important to assess trees which display signs of injury or any external defect for decay columns even if there is no conk or fruiting body present, as these defects are possible infection courts for stem rot fungi, and fruiting bodies usually only form when decay is advanced.

There are many ways to assess rot in trees, as described in the "Inspection Tools" section of this document. The simplest method is sounding with a mallet or other tool. It should be noted that sounding aspen is not recommended due to their limited defenses against canker or decay pathogens. If severe stem decay is suspected with aspen, particularly if fruiting bodies are present, removal of the tree can be justified rather than sounding and potentially wounding the tree and initiating more decay. Another common method used to assess level of decay is to use a borer or drill. This method is necessary even if sounding has been performed because a tree that sounds hollow may have enough structural wood to be considered sound. Again, boring or drilling aspen is not recommended; trees with suspect structural integrity represent hazards that should be mitigated.

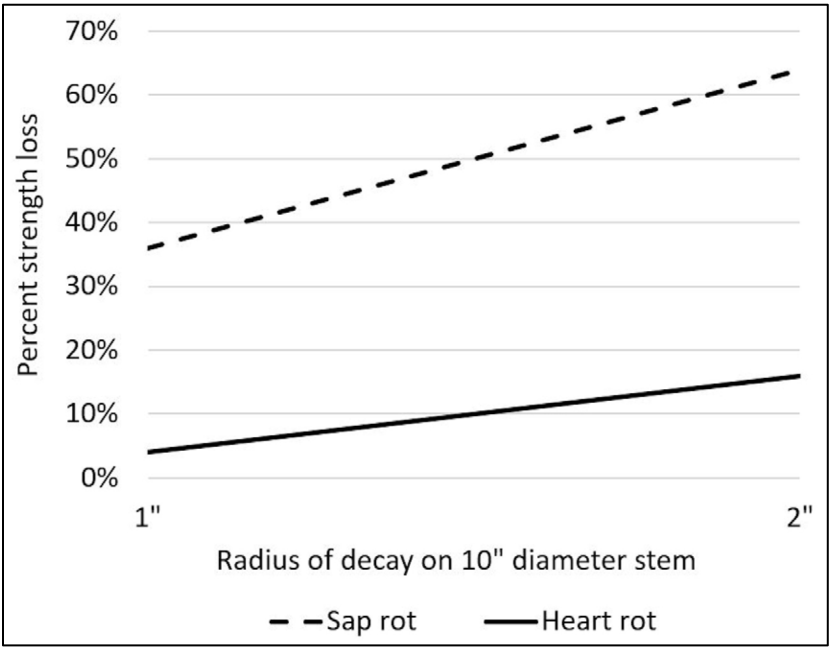

Figure 30. Strength loss for 1" or 2" of decayed wood on a 10" diameter tree, with a sap rot or heart rot.

Assessing Loss of Wood Strength

Tables 1 and 2 can be used to calculate wood strength loss due to decay. The assessor must consider aggravating conditions that affect interpretation of sound wood measurements, such as lean, shape of the wound and/or cavity, fissures in the shell, etc.

Use Table 1, adapted from the Region 1/4 hazard tree guide (USDA Forest Service 2017a), to determine defect severity based on percent sound shell in trees without external defects. Refer to Wagener (1963) for a more complete discussion of assessing loss of wood strength in trees without external defects. The values in Table 1 are based on precise calculations according to an equation developed by Wagener (1963). In lieu of the table, however, a simple rule of thumb can also be used for determining sound wood necessary to maintain adequate strength in trees with stem decay and no external wound/defect. There must be one inch of sound wood per every six inches of diameter. If less than one inch of sound wood per every six inches of diameter is present, the tree in question represents a significant hazard.

Table 1. Reference sound wood shell thicknesses[1] for determining failure potential of trees with different within-bark tree diameters. Trees with sound shell below the 33% column rate as a 3 for defect severity, trees between the 33% and 60% columns rate as a 2 for defect severity.

Within-Bark Tree Diameter in Inches[2]	Inches Radius for 33% Sound Wood Shell	Inches Radius for 60% Sound Wood Shell
6	1.0	1.8
8	1.3	2.4
10	1.7	3.0
12	2.0	3.6
14	2.3	4.2
16	2.6	4.8
18	3.0	5.4
20	3.3	6.0
22	3.6	6.6
24	4.0	7.2
26	4.3	7.8
28	4.6	8.4
30	5.0	9.0
32	5.3	9.6
34	5.6	10.2
36	5.9	10.8
38	6.3	11.4
40	6.6	12.0
42	6.9	12.6
44	7.3	13.2
46	7.6	13.8
48	7.9	14.4

[1] Compare average of bole measurements at bole height of greatest weakness or defect to values in column; if tree measurement is less, record as the higher failure potential value.

[2] Values for most diameters not shown can be calculated by halving, doubling, or averaging.

Many trees with stem decay have major wounds, defects, or other openings where the decay was initiated. In these cases, more sound wood is necessary to maintain strength. Smiley and Fraedrich (1992) developed an alternate equation for assessing strength loss in these trees with external openings. The previously mentioned rule of thumb can be expanded for these trees as follows, depending on the percentage of the circumference occupied by the opening:

- 1.5” of sound wood for every 6” of diameter (opening <15% of circumference)
- 2” of sound wood for every 6” of diameter (opening 15-30% of circumference)

Table 2 below shows a range of sound wood thicknesses necessary to maintain strength for a similar range of diameters in trees with openings/wounds/defects in addition to significant decay.

Table 2. Reference sound wood shell thicknesses[1] for determining failure potential of trees with different within-bark tree diameters and external wounds/defects/openings occupying up to 30% of the circumference. Trees with sound shell below the minimum listed value rate as a 3 for defect severity.

Within-Bark Tree Diameter in Inches[2]	Inches Radius for Opening <15% of Circumference	Inches Radius for Opening 15-30% of Circumference
6	1.5	2.0
8	2.0	2.7
10	2.5	3.3
12	3.0	4.0
14	3.5	4.7
16	4.0	5.3
18	4.5	6.0
20	5.0	6.7
22	5.5	7.3
24	6.0	8.0
26	6.5	8.7
28	7.0	9.3
30	7.5	10.0
32	8.0	10.7
34	8.5	11.3
36	9.0	12.0
38	9.5	12.7
40	10.0	13.3
42	10.5	14.0
44	11.0	14.7
46	11.5	15.3
48	12.0	16.0

[1] Compare average of bole measurements at bole height of greatest weakness or defect to values in column; if tree measurement is less, record as the higher failure potential value.

[2] Values for most diameters not shown can be calculated by halving, doubling, or averaging.

Common Stem Decay Fungi in the Southwest

Red belt fungus, *Fomitopsis schrenkii* (formerly *F. pinicola*)
Hosts: Conifers and sometimes aspen
Decay type: Brown rot
Defect value: 3

Red belt fungus is one of the most common decay fungi in conifer forests of the Southwest (Figure 31). It is an important saprophyte, decaying the sapwood of dead trees, and its characteristic cubical brown rot can commonly be found in slash piles and on dead trees. It is generally not an aggressive pathogen, but can cause heart rot in living trees, particularly mature trees with trunk wounds. It has been associated with major hazard tree failures in living but fire- or lightning-damaged ponderosa pine. The pathogen is rarely an issue in young trees and is most commonly found fruiting on dead trees. Fruiting bodies occasionally occur on dead parts of live trees, however, and sometimes failure of live trees can occur in the absence of conks (Figure 32). Dead trees should be removed or otherwise mitigated regardless of decay. Fruiting bodies or extensive brown rot on living trees warrant removal of the affected tree or other mitigating action.

Figure 31. Red belt fungus fruiting body.

Figure 32. Failed live spruce tree due to *Fomitopsis schrenkii* decay.

Red rot, *Dichomitus squalens*
Hosts: Ponderosa and pinyon pines
Decay type: White heart rot
Defect value: 2 (3 if on limbs 6+" in diameter)

This is one of the more common stem decay fungi found in ponderosa and pinyon pines, especially old growth ponderosa pine. It produces flat, white to yellow fruiting bodies that are often found on the underside of dead branch stubs or in slash piles (Figure 33). Fruiting bodies in slash piles are often found on the underside of decaying material in contact with the soil. It is not an aggressive pathogen, and associated signs and symptoms of decay can be considered a moderate hazard and monitored. Large limbs with red rot may need to be pruned if hanging over a target.

Figure 33. Red rot fruiting body on a ponderosa pine.

Red ring rot, *Porodaedalea pini* (Figure 34)
Hosts: Conifers
Decay type: White heart rot
Defect value: 2 for 1-2 conks, 3 for > 2 conks

Porodaedalea pini is an aggressive decay fungus which primarily decays the heartwood of living trees. It is considered one of the most common stem decay fungi in North America. In the Southwestern Region, it is commonly found in mixed conifer and spruce-fir forests, being especially common in mature forests and old growth trees. It can be quite common on Engelmann spruce, Douglas-fir, and southwestern white pine. Red ring rot causes extensive decay in the heartwood of severely infected trees, with decay columns up to 30' long, and is therefore an important pathogen for tree risk assessors to be familiar with. Greater than two conks indicates significant decay (Figure 35). If they are occurring in the lower trunk of the tree, take core samples or drill to test the tree for soundness. Multiple conks can often be found spiraling up the trunk in old growth Douglas-fir, often associated with old branch stubs. Punk knots, dense masses of brown mycelium that may extend from a decayed branch stub, may also be found with this disease.

Figure 34. Red ring rot fruiting body.

Figure 35. More than two red ring rot conks found on a single tree indicate major decay.

Indian paint fungus, *Echinodontium tinctorium*
Hosts: True firs, sometimes Douglas-fir or spruce
Decay type: White heart rot
Defect value: 3

Indian paint fungus is a common and very important heart rot in the Southwest, most often found on mature true fir. This is an aggressive decay fungus causing many hazard tree issues in mature mixed conifer and spruce-fir forests. The presence of conks is a reliable indicator of extensive decay, with one conk indicating a decay column up to 40’ in length. Trees with one or more conks represent high failure potential and should be removed or otherwise mitigated. Conks are easy to identify because of the teeth-like structures found on the underside of the fruiting body where spores are produced (Figure 36). Conks of most other common stem decay species in the Southwestern Region have pores rather than these teeth-like structures. Conks are frequently found associated with old branch stubs where the fungus first entered the stem and may be found high on the bole (Figure 37). Care should be taken when removing any trees infected by this pathogen, but especially when the decay is occurring high on the bole. In these cases, the tree may start to fall in the desired direction but can buckle midway up the trunk, resulting in the top falling back on the sawyer. Punk knots may also be found with this disease.

Figure 36. Indian paint fungus fruiting body.

Figure 37. Fruiting body of Indian paint fungus growing high on the bole of an infected tree.

False tinder conk, *Phellinus tremulae*
Hosts: Aspen
Decay type: White heart rot
Defect value: 2 for one conk; 3 for > one conk, conk + defect

False tinder conk is a very common heart rot encountered on aspen. It is ubiquitous throughout the host range and can be found in most aspen clones. The pathogen generally enters through branch stubs, which can provide an easy entry point and give access to heartwood, but may also enter through wounds or be introduced by insects. Conks are hoof-shaped and brown to black in color on the often cracked upper surface (Figure 38). The lower, spore-bearing surface has pores and is tan to white or grey in color. A single fruiting body of *P. tremulae* may warrant removal of an aspen tree with a target if there is a major crack or wound or some other associated compounding defect, and trees with multiple conks should be removed or otherwise mitigated regardless of additional defects. Aspen lacks many of the protective chemicals other trees have to defend themselves against fungal pathogens and is very susceptible to this stem decay fungus and many other fungal pathogens. Therefore, it is highly recommended that new recreation areas should not be developed in aspen groves.

Figure 38. False tinder conk on an aspen stem.

Pouch fungus, *Cryptoporus volvatus*
Hosts: Bark beetle-killed conifers
Decay type: White sap rot
Defect value: 3; take care when removing – severe sap rot

Cryptoporus volvatus is not an aggressive pathogen but rather colonizes trees recently killed by bark beetles, generally within one to two years of tree death. This fungus causes a grayish white rot in the first couple inches of outer sapwood of freshly killed trees. Fruiting bodies, which may emerge out of bark beetle exit holes on the bole of infected trees, are the best diagnostic feature for this fungus (Figure 39). The small, tan-colored fruiting bodies have a sheath covering the spore producing surface on the underside, which is where the common name pouch fungus originates. Because trees with *C. volvatus* conks have typically been dead for at least a year, quick removal of trees is recommended. Care should be taken during removal of trees affected by this decay, however, as the sap rot it causes may significantly reduce sound wood.

Figure 39. Pouch fungus fruiting bodies.

Stem decays of other hardwoods
Defect value: 3 for *Inonotus munzii* on cottonwood, otherwise 2

Stem decays are rather ubiquitous in hardwoods, particularly in Arizona sycamores, cottonwoods, and oaks. This presents a significant challenge to tree risk assessors. Though most riparian hardwood species display signs and symptoms of stem rot on the main stem, most failures in these species tend to be in large, extended to overextended branches. Particular attention should be focused on large branches and their associated branch unions. Fruiting bodies close to or on these branches represent a high hazard.

Inonotus munzii and *I. arizonicus* are the two main stem decay fungi of cottonwood and Arizona sycamore in the Southwestern Region, respectively, causing extensive white rot in the boles and branches of host trees. Both fungi, particularly *I. munzii*, may be commonly observed growing in large clusters and/or on the underside of large limbs (Figure 40). Branch dieback and failure is common on trees affected by these fungi.

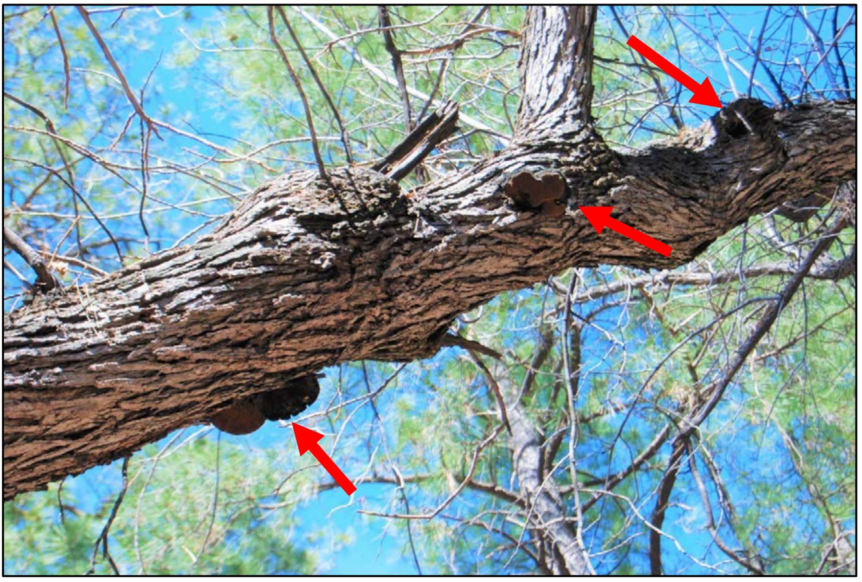

Figure 40. Multiple *Inonotus munzii* fruiting bodies growing on a cottonwood limb.

A number of stem decay species affect oaks in the Southwestern Region, including *Phellinus everhartii*, *I. dryophilus*, and the canker rot pathogen *I. andersonii*. *Phellinus weirianus* causes a white rot of walnuts (Figure 41), and a number of other stem decays occur throughout the Region on less common hosts. Generally speaking, all tree species have at least one associated decay fungus, and most of these produce conks as fruiting bodies. Though there are differences between conks in form and color, they are usually tough and hoof-shaped with spores produced in pores on the underside of the fruiting body. An in-depth description of stem rots that affect hardwoods can be found in Glaeser and Smith (2010, 2013).

Figure 41. *Phellinus weirianus* fruiting bodies on an Arizona walnut.

Root Disease

Root disease, or root rot, is caused by a variety of fungi which parasitize the roots of a wide range of host species. In general, true firs, spruce, and Douglas-fir are the most susceptible species to root disease in the Region, although susceptibility varies by age, site, and genetics of the host and pathogen. Root diseases are a serious concern in developed recreation areas, and root disease centers should be avoided when planning new recreation sites. Sites already built within areas that have root disease issues should either be moved, closed, or converted to a younger age structure due to the danger root disease presents. Intensive actions may also be employed through vegetation management to remove susceptible species and replace them with more resistant species such as southwestern white pine or ponderosa pine, unless these species are being affected by root disease on the site (e.g., *Armillaria* infecting southwestern white pine).

Root diseases have been associated with many tree failure incidents throughout the United States and are therefore a major concern in developed recreation sites. Root disease fungi cause the decay of roots and butts (lower bole) of host trees, severely compromising the structural integrity of the tree. Fungi associated with root disease will often interfere with the movement of water and nutrients, potentially resulting in a loss of host vigor. One exception is *Phaeolus schweinitzii*, which only affects the heartwood of host trees and does not cause crown symptoms. In addition, root diseases predispose trees to bark beetle attacks, windthrow/stem breakage, and premature mortality.

Root disease can spread by root-to-root contacts or by spore dispersal. Species which spread by root-to-root contact will generally form pockets of dead and dying trees. Spore dispersal can spread root diseases long distances through airborne spores. Management activities like thinning infected stands of true fir can exacerbate disease, as spores are able to infect freshly cut stumps. Fire suppression has led to an increase in root disease in many areas, as it favors succession from pines and other more fire adapted species to true firs. The large increase in true firs, which are highly susceptible to most root diseases, has led to an increase in root disease on the landscape. In many cases, severe root rot can be attributed to management activities, particularly for Heterobasidion root disease in white fir.

Root disease is commonly referred to as a disease of the site because many of these pathogens can persist in soil on old woody debris for decades, surviving as saprophytes. When new hosts start growing, root disease pathogens are able to expand from a saprophyte in a dead tree to a parasite infecting a living tree. Therefore, recreation sites built within areas with root disease will have chronic hazard tree issues, and placing recreation sites in these areas is strongly discouraged. Moving or closing sites which were previously built within root disease areas is advised. If a site is to remain open, species conversion is recommended. Ponderosa and southwestern white pines and hardwoods like oaks are generally the most tolerant/resistant to root diseases in the Southwest but are not immune. Though these species are generally the best options for root disease affected areas, caution must be exercised, and all trees must be assessed for signs and symptoms of disease. Sites which have no options for alternative species may need to be closed, moved, or maintained in a younger age structure. Contact Forest Health Protection for additional assistance.

General Signs and Symptoms of Root Disease

Depending on the host and the pathogen, root disease signs and symptoms may include all or some of the following:

1. Decline in crown health, including chlorotic or yellowing needles, stunted or “bottle brush” new growth, and premature needle shed.
2. High levels of dead branches resulting in thinning crowns. In older trees, branch mortality will progress from outside in. In younger trees, this mortality may manifest from the inside out.
3. Large cone crops, commonly referred to as stress crops.
4. Basal resinosis, or sap oozing from the lower bole of the tree, and/or bark staining.
5. Evidence of butt rot. It may be necessary to use a drill or borer to determine presence of butt rot.
6. Pockets of dead and dying trees. There will generally be trees at different stages of mortality with some completely dead and others just starting to show decline. The oldest dead will be in the center of the pocket with dying trees at the fringe of the pocket. Root disease may also manifest in a linear, or vein-like, pattern.
7. Large pockets of windthrow or dead and down trees.
8. Lack of roots or the presence of rotted roots on downed trees.
9. Pockets of bark beetle activity may be indicative of root disease.
10. Signs of the causal agent, including fruiting bodies and mycelium on roots or under bark at the base of infected trees.

Common Root Diseases in the Southwest

Armillaria root rot or shoestring root rot, *Armillaria* spp.
Hosts: Any species
Decay type: Spongy, yellowish white root rot

Armillaria root rot, caused by various *Armillaria* spp., is the most common root disease in the Southwest, accounting for up to 80% of all root disease-related mortality in the Region. Fruiting bodies are gilled mushrooms, formed singly or in clusters at the base of or near infected trees (Figure 42). These fruiting bodies can be rare in the Southwest, but common signs in the Region include white mycelial fans growing just underneath the bark of infected trees at the root collar and on infected roots (Figure 43) as well as root-like rhizomorphs growing along infected roots (Figure 44). Both of these structures are composed of fungal tissues called hyphae or mycelium.

Figure 42. Mushroom fruiting bodies associated with Armillaria root rot form near the base of an infected corkbark fir.

Figure 43. Mycelial fan associated with Armillaria root rot.

Figure 44. Root-like rhizomorphs associated with Armillaria root rot.

Root-to-root spread occurs commonly with Armillaria root disease, and infection centers may expand as long as new host material is available. These infection centers have gotten as large as 2 miles in diameter in northeast Oregon. Infection centers are typically smaller in the Southwest, but the pathogen may nevertheless persist in soil, acting as a saprophyte and breaking down old woody debris on infected sites for decades. For this reason, Armillaria root rot is often referred to as a disease of the site. All species in the Region may be affected, but certain host species may do better than others on certain infected sites for a variety of reasons; these hosts should be favored over time.

Recreation sites should not be developed in areas with significant Armillaria root rot problems. In preexisting developed areas, Armillaria root rot-affected trees should generally be removed along with highly susceptible neighboring hosts, such as true firs. Maintaining a younger age structure or implementing site closures may be warranted as well, depending on the severity of the situation.

Heterobasidion root rot, *Heterobasidion occidentale*
Hosts: True firs
Decay type: White rot

Heterobasidion root rot is another root disease frequently encountered in the Southwestern Region. The pathogen species affecting true firs, *Heterobasidion occidentale*, is fairly common in white fir (see discussion in Worrall et al. 2010). Another species, *H. irregulare*, infects ponderosa pine but is rare in the Region, found more often on limestone soils (Worrall et al. 2010). Like *Armillaria* spp., *Heterobasidion* spp. are also able to survive as saprophytes, living on dead material for many years, and can therefore be considered long-term chronic issues on sites where they are identified. Conk-like fruiting bodies of various sizes often form inside hollow stumps, making them difficult to find (Figure 45), though they can occur on the outside of stumps in wetter spruce-fir forest types. They are brown in color on the upper surface, and the lower surface is white to tan in color and produces spores in pores. Numerous popcorn-like fruiting bodies may be found in stumps.

Figure 45. Fruiting bodies of *Heterobasidion occidentale* that were found in a hollow stump.

Laminated decay can also occur, with wood separating on annual growth lines (Figure 46). Wood staining can be found in affected trees by cutting into their base, although this should only be done for trees with targets if removal of the tree is already planned (Figure 47). Root-to-root spread also occurs with this disease, and any true fir adjacent to a stump with fruiting bodies or a tree that fails because of this disease may also be preemptively removed. Heterobasidion root disease commonly causes butt rot in host trees, particularly in true firs. Many of the tree failures associated with this disease occur in the lower bole of the affected tree. Assessing old stumps for signs of past heart rot, which would leave a hollow stump, is another good indicator of Heterobasidion root disease (Figure 48). Management should be long term and will likely require species conversion or movement of the recreation site. Partial cutting in mixed species stands with the focus of selecting for species that appear least impacted is recommended. Partial cutting is not recommended in pure stands of infected true fir. Species conversion or moving the site are likely the most effective options in these cases.

Figure 46. Laminated decay associated with Heterobasidion root rot, where the wood separates at annual growth rings.

Figure 47. Reddish brown staining revealed by cutting into the base of a *Heterobasidion occidentale*-infected white fir.

Figure 48. Hollow stump of a true fir with Heterobasidion root rot; fruiting bodies are visible inside the hollow.

Ganoderma root rot or artist's conk, *Ganoderma applanatum*
Hosts: Aspen
Decay type: White mottled rot
Defect value: 3

Ganoderma root rot causes a severe root disease on aspen in the Southwestern Region and can be the cause of significant hazard tree issues. The disease mainly affects older, larger aspen stems. Roots smaller than 2" in diameter are seldom infected. Failure of green trees can be common, and the best signs and symptoms to look for are fruiting bodies at the base of stems (Figure 49) and windthrow of nearby trees in varying directions with limited to no root balls attached. Crowns of windthrown trees may be green, healthy, and display no obvious symptoms of problems in the root system prior to failure (Figure 50). Fruiting bodies can be reddish brown to grayish in color on the upper surface and white on the spore-producing underside. The spore producing surface can be easily bruised and turn a dark brown color; the staining becomes permanent upon the conk drying out, thus giving the fungus its common name, artist's conk. As previously mentioned, aspen are prone to many health concerns. If possible, plan for species conversion in developed recreation sites dominated by aspen. Otherwise, regenerating stands of aspen that have Ganoderma root rot and maintaining a younger age structure will be the best course of action. Any trees with *Ganoderma applanatum* fruiting bodies should be removed, or other mitigating actions should be taken (e.g. site closures). Like other root disease pathogens, *G. applanatum* can remain on site for long periods of time and cause problems in older aspen stems and roots. It is highly recommended that new recreation sites, campgrounds, and parking lots not be developed within aspen groves.

Figure 49. Fruiting bodies of *Ganoderma applanatum* growing near the ground on its aspen host.

Figure 50. Failed aspen with a green crown, demonstrating that thorough inspection of the base of the tree is necessary for effective tree risk assessments.

Schweinitzii root and butt rot or cow patty fungus, *Phaeolus schweinitzii*
Hosts: Douglas-fir, rarely other conifers
Decay type: Brown butt rot

Schweinitzii root and butt rot is most common in older stands, especially old growth Douglas-fir. This propensity to infect older trees makes this pathogen relatively rare on the landscape, as old growth components of many national forests in the region are relatively small. Many recreation areas have been placed in areas with large old trees, however, and therefore have an increased probability of *Phaeolus schweinitzii* being present. Failure from this disease is typically of the lower bole of large old trees with advanced decay. Fruiting bodies can be quite large, up to 1.5’ in diameter, are typically dark brown in color, and often incorporate debris and small herbaceous plants from the forest floor as they grow (Figure 51). These fruiting bodies may resemble cow patties, hence one of the common names of the fungus, and they will typically grow out of infected roots through the soil away from the trunk of the infected tree. This disease causes a brown rot in the roots and base of infected trees, sometimes leading to butt swelling. This pathogen does not spread from root-to-root and is not associated with root disease pockets. Rather, each infection is initiated by spores percolating through the soil and infecting via root tips. This pathogen does not produce crown symptoms and can be difficult to detect. The main signs and symptoms to look for are conks in the root zone and a swollen base. Old growth trees, particularly Douglas-fir, should be assessed thoroughly if any of the above symptoms or signs are observed. Remove affected trees or otherwise mitigate if decay is advanced; stem decay guidelines may be used for decay in the butt.

Figure 51. *Phaeolus schweinitzii* fruiting body with incorporated herbaceous plants.

Tomentosus root rot or velvet top fungus, *Onnia tomentosa*
Hosts: Spruce most commonly, sometimes corkbark fir
Decay type: White pocket rot

There is little information on the extent and damage caused by this pathogen in the Southwest. It has been observed with some frequency in spruce-fir forests of the region and, therefore, is another disease that tree risk assessors should be familiar with. This pathogen is capable of causing significant loss of structural integrity and can therefore create hazard tree issues in developed sites in spruce-fir forest types. Root-to-root spread may occur, and this disease is commonly found in pockets. Long distance spread by spores landing in wounds on susceptible host trees may occur as well. Fruiting bodies may be similar in appearance to those of *P. schweinitzii*, and they are similarly often found growing from the soil in the root zone of infected trees (Figure 52). The fruiting bodies of *Onnia tomentosa* are much smaller (less than 4” in diameter) and generally lighter brown in color than those of *P. schweinitzii*, however, and host preferences and decay types are different between these two diseases as well. Wood decayed by *O. tomentosa* has a honeycomb-like appearance in cross-section due to the associated white pocket rot. Remove susceptible host trees or otherwise mitigate in developed recreation sites if this fruiting body is found nearby and/or obvious root disease symptoms are occurring (e.g., advanced crown dieback, honeycomb-like decay in cross-section of neighboring failed spruce).

Figure 52. *Onnia tomentosa* fruiting body.

Hazard Tree Mitigation

A number of mitigation methods are available for hazard tree management. The most common and generally the easiest is removal of the hazard tree. Conifers should be bucked for quick drying and reduced chances of increasing bark beetle populations; material can be left onsite and will typically be used by visitors for firewood. If live trees will be felled and left on site, particularly ponderosa pine, Douglas-fir, or spruce, it is recommended that operations be limited to July through January to reduce the chances of attracting bark beetles. Some defects that generally warrant full tree removal if a high priority target is present include unnatural leans, root disease, severe stem decay, and severe cracking.

Pruning is another common mitigation method. Pruning may be recommended for dead tops and branches, large brooms, overextended branches, and other limbs with poor architecture. This can also be a relatively cheap and simple mitigation method for hazardous limbs lower in the tree. Pruning hazards that are high in a tree crown may require the use of a bucket truck or tree climber, which can be expensive and not readily available. In some cases, removal of the tree may be easier than pruning. Costs of mitigation must be balanced with the availability of resources. As with full tree removal, if the material is to be left on site, pruning should occur between July and January to reduce the chances of attracting bark beetles.

Moving the target may sometimes be a viable mitigation method, provided the target can then be secured in some way to avoid visitors moving it back to within striking distance of the hazard tree. An example would be moving picnic tables away from a hazardous cottonwood that recreation staff are hesitant to remove due to its aesthetic value. The picnic tables must be secured in their new location. Building pavilion structures for picnic tables is a great way to move targets away from beautiful trees and still provide desirable shade.

Site closures may be necessary in certain hazard tree scenarios. For example, a particularly hazardous but aesthetically valuable tree that has a high priority target like a campsite may warrant closing only that campsite to preserve the tree. Entire recreation areas may need to be closed if hazard tree issues are too numerous to manage. These closures may be permanent or temporary, depending on the situation.

Some creativity may be required in mitigating hazards and maintaining desirable recreation sites. Forest Health Protection in the Southwestern Region is available to assist with especially complex sites. Vegetation management plans can be quite helpful in long-term tree risk planning and represent a proactive, rather than reactive, response to hazard tree issues. Forest Service Region 2 has an excellent Vegetation Management Planning Guide that may be helpful to federal recreation staff in the Southwestern Region as they develop their vegetation management plans (USDA Forest Service 2002).

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Appendix 1: Common Forest Types of Developed Sites in the Southwest

The forest type of the area being surveyed plays an important role in tree risk assessments and hazard tree mitigation. Certain forest types may be more suitable for developed recreation sites, and the intensity of tree risk assessments may vary depending on the common defects present in a given type.

Pinyon-Juniper Woodland

Key species: two-needle pinyon pine (*Pinus edulis*) and several junipers (*Juniperus* spp.)

This forest type usually occurs between 5,000’ and 7,000’ elevation in the Southwestern Region. Junipers usually have scale-like leaves (Figure 53) and berry-like cones, while pinyon pines most commonly have short pairs of needles and small, open cones (Figure 54). In general, pinyon pine and junipers are less likely to be major hazard tree issues than tree species in other forest types of the Region. These trees tend to be relatively small in stature, resulting in smaller target zones and less potential damage when failures do occur. Both are also somewhat resistant to decay fungi, though red rot (*Dichomitus squalens*) and Armillaria root rot can occur in pinyon pine, and some stem decays are found in juniper. Developed sites in this forest type should still be inspected annually, but fewer trees in any given area will likely need to be monitored over time due to limited target areas and decay resistance.

Figure 53. Scale-like leaves of a Rocky Mountain juniper.

Figure 54. Small, round cone and pairs of needles on a two-needle pinyon pine.

Ponderosa Pine

Key species: ponderosa pine (*P. ponderosa*), sometimes Gambel oak or live oak species (*Quercus* spp.)

This is one of the most widespread forest types in the mountains of the Southwestern Region, and is usually found between 6,000’ and 8,500’ elevation. Ponderosa pine has orange, fissured bark when mature; this tree also has long needles in groups of three and medium-sized, prickly cones (Figure 55). They are one of the better hosts for developed recreation areas because they are quite decay resistant. Severe stem decay, often due to red belt fungus (*F. schrenkii*), can occur in lightning- or fire-damaged trees, and these should be inspected closely. Large dead limbs often occur and can develop red rot (*D. squalens*). Dwarf mistletoe brooms can also be common. Pruning dead limbs, as well as mistletoe brooms where possible, can reduce hazard risk and improve vigor of the trees. Codominant stems can occur frequently in some sites; the hazard should be mitigated if cracking and/or obvious decay is present or after failure of one of the stems. Bark beetle activity can cause large pockets of mortality. Sometimes individual trees are strip attacked, leading to mortality, decay, and eventual failure of one side of the tree. Actions such as brood tree removal, which can help to mitigate bark beetle outbreaks, may be implemented in recreation areas if the infestation is observed early in its development.

Figure 55. Medium-length needles in groups of three and prickly young cones on a ponderosa pine.

Mixed Conifer

Key species: Douglas-fir (*Pseudotsuga menziesii*) and white fir (*Abies concolor*)

Mixed conifer occurs at higher elevations (7,800’ to 9,800’ elevation), where Douglas-fir and white fir are the dominant tree species. Douglas-fir trees have cones with bracts resembling the back half of a rodent, as well as single needles that narrow at the base (Figure 56). White fir trees have rounded, blueish-green needles with the point of attachment to the stem resembling a suction cup (Figure 57) and cones that disintegrate at maturity. Southwestern white pine and limber pine can occur as well and are common in some areas; these trees have moderately long needles in groups of five and large cones. Root diseases are very common in this forest type, especially those caused by *H. occidentale* in white fir, *Phaeolus schweinitzii* in Douglas-fir, and *Armillaria* spp. in all hosts. Severe stem decay can be common, especially Indian paint fungus (*E. tinctorium*) and red ring rot (*Porodaedalea pini*). Dwarf mistletoe brooms are very common in Douglas-fir. Fir broom rust is common in white fir in the Region and ubiquitous in some parts of New Mexico. Favoring Douglas-fir over white fir is generally recommended in these sites. Southwestern white and limber pines should also be favored where they occur, along with ponderosa pine in drier mixed conifer sites. White pine blister rust caused by *Cronartium ribicola*, a disease characterized by blister-like fruiting structures called aecia (Figure 58), may cause top-kill and large dead limbs in white pines where the disease occurs, which may warrant pruning (Figure 59). Douglas-fir is vulnerable to bark beetle activity following blowdown events, which can spread to living trees and cause mortality. Taking proper action, such as debarking or removing fresh blowdown, will help to mitigate impacts from bark beetles.

Figure 56. Douglas-fir branch bearing an immature cone with rodent-like bracts.

Figure 57. White fir needles with point of attachment to stem resembling a suction cup.

Figure 58. White pine blister rust aecia.

Figure 59. Branch dieback due to white pine blister rust.

Spruce-Fir

Key species: Engelmann spruce (*Picea engelmannii*) and corkbark fir (*Abies lasiocarpa* var. *arizonica*)

This forest type generally occurs at high elevations above 9,800’ elevation in the Southwestern Region, where Engelmann spruce and corkbark fir are the dominant tree species. Engelmann spruce trees often have branch tips with cone-like galls due to an insect pest (Figure 60) and produce small cones resembling those of Douglas-fir but without the rodent-like bracts. They have sharp, stiff, and square needles and flaky, potato chip-like bark (Figure 61). Corkbark fir trees have smooth, corky bark (Figure 62); rounded, flexible, and flat needles; and their cones disintegrate at maturity. Root disease pathogens may be common in this forest type, especially *O. tomentosa* on spruce and *Armillaria* spp. on either host. Shallow root systems occur, so windthrow may be common even in the absence of root disease. Stem decays can be common as well, especially red ring rot (*Porodaedalea pini*) in spruce. Both species can be infected by broom rusts, though this is not typically a severe hazard unless on the main stem. Dwarf mistletoe can occur on spruce in select areas of the region. Spruce is also very vulnerable to bark beetle activity. Blowdown events, which can be common in spruce, may lead to increasing spruce beetle populations. Taking proper action, such as debarking or removing fresh blowdown, will help to mitigate impacts from bark beetles. This forest type should usually be managed for a younger age structure when it occurs in developed recreation sites, particularly if root rot is a concern.

Figure 60.Cooley spruce gall adelgid-caused galls on Engelmann spruce branch tip.

Figure 61. Flaky, potato chip-like Engelmann spruce bark.

Figure 62. Smooth and corky-textured bark of a corkbark fir.

Aspen

Key species: aspen (*Populus tremuloides*)

Aspen-dominated areas are not recommended for developing new recreation sites because of numerous hazards. Aspen have distinctive white-colored bark (Figure 63) and spade-shaped, deciduous leaves. The thin, living bark is easily wounded by wildlife and visitors eager to carve their initials, an activity that should be discouraged. Wounds can be colonized by pathogens causing canker diseases and stem decay, particularly sooty bark canker (*Encoelia pruinosa*) and false tinder conk (*Phellinus tremulae*), respectively. Ganoderma root rot commonly occurs and can cause complete failure of green, otherwise healthy-looking trees. Aspen should be inspected at their base for conks, and any trees with obvious signs of this root disease should be removed, or site closures should be implemented. Where recreation sites already occur in aspen dominated areas, aspen can be managed in a younger age structure if wildlife browsing is not prohibitive.

Figure 63. Small group of aspen trees showing characteristic white bark.

Riparian

Key species: cottonwoods (*Populus fremontii*, *P. angustifolia*, *P. deltoides*), Arizona sycamore (*Platanus wrightii*), sometimes velvet ash (*Fraxinus velutina*), Arizona alder (*Alnus oblongifoloia*), Arizona walnut (*Juglans major*), Arizona boxelder (*Acer negundo arizonicum*), netleaf hackberry (*Celtis reticulata*), or blue spruce (*Picea pungens*)

Forests along waterways in the region present unique ecosystems as well as unique hazard tree challenges (Figure 64). Arizona sycamore and various cottonwood species are common. Various other hardwoods can be common as well at certain sites. Blue spruce may occur in higher elevation areas in portions of the region. High water tables, coarse soil structures, and shallow root systems can combine to cause significant windthrow in these areas. Stem decays are common in riparian hardwood species. Large limbs of cottonwood and Arizona sycamores present significant hazard issues and can fail in the absence of decay. Large branch dieback may be caused by *I. munzii* and other stem decays, as well as chronic infections by the foliar disease sycamore anthracnose (Figure 65). Particular attention should be focused on the crowns of these species, assessing overextended branches and decay associated with large branches and branch unions. Crowns should also be thoroughly assessed for dead branches. Development of new recreation sites in cottonwood stands is not recommended due to these issues. In already established areas with older growth Arizona sycamore, extensive stem decay issues may warrant closing some sites to maintain islands of larger trees and avoid completely clearcutting entire recreation areas.

Figure 64. Riparian area on the Gila National Forest with large hardwoods growing along a river in an otherwise arid, juniper savanna ecotype.

Figure 65. Heavy defoliation of an Arizona sycamore due to the disease sycamore anthracnose; repeated infections can lead to large branch dieback.

Appendix 2: Tree Risk Assessment Form

USDA Forest Service | **Tree Risk Assessment Form** | Southwestern Region

Location: ______________________________ Page: _______ of _________

Date: ____________________ Inspected by: ______________________________

(Each column represents one tree)

Unit number (e.g. campsite #)							
Tree number							
Tree species							
DBH (in)							
Height (ft)							
Tar-gets	2	People, Permanent Structures, Vehicles					
	1	Major Trails and Roads					
Defects	3	Wounds/cankers > 50% of circumference					
		Height to diameter ratio over 80:1 (see back of form[4])					
		Unnatural lean					
		Root disease					
		Severe stem decay signs (see back of form[5])					
		Exposed roots with decay, > 50% of roots					
		Crack severe or associated with fork					
		Dead tree					
		Sound shell < 33% radius*					
		Dead Top/Branch > 6″ in diameter					
	2	Wounds/cankers 33-50% of circumference					
		Height to diameter ratio 60:1 to 80:1					
		Exposed roots with decay, < 50% of roots					
		Cavities in branch, bole, base					
		Codominant stems with included bark					
		Dead Top/Branch 3-6″ in diameter					
		Sound shell 33-60% radius*					
		Moderate stem decay signs (see back of form[6])					
	1	Wounds/cankers 10-33% of circumference					
		Lightning scar, small crack					
		Large broom, dead top/branch < 3″ diameter					
		Codominant stems with no included bark					
		Exposed or severed roots, no decay					
		Natural lean					
	0	No visible defect; minor wounds, pitch/flux					
		Risk Rating (Target x Worst Defect)					
		*Drilling (if done) – inches of sound wood					
		GPS Coordinates					
		Remove					
		Prune					
		Monitor					
		Date Accomplished					
		Notes					

Use of the Tree Risk Assessment Form

Defective trees are potential hazards to people and property in recreation areas. Indicators of defects are used to identify trees that may fail. Systematic, annual, documented inspections of trees in recreation sites and corrective action are recommended to reduce hazards to the public. (D.W. Johnson. 1981. Tree hazards, Recognition and Reduction in Recreation Sites. Technical Report R2-1. USDA Forest Service, Forest Pest Management Denver, CO.)

The Tree Risk Assessment Form is more than a rating record of potential tree hazards for a particular site. It is a record of the overall structural condition of a tree that can be used to determine progression of defects over time and to document the frequency of certain defects. All defects observed should be checked even though only the highest values are used in the risk rating.

Forms cannot take all situations into account. Trained and experienced evaluation crews may need to exercise judgment in some cases. However, if you need to regularly override the form, need training, or have any questions about the process or a rating a particular tree defect, please contact Forest Health Protection staff:
Arizona Zone Office: (928) 556-2075 **New Mexico Zone Office**: (505) 842-3288

1. Maps of the campgrounds are helpful in planning and performing tree risk assessments. All recreation structures should be drawn on the maps. Maps used or created during the survey should be included with the Tree Risk Assessment Forms to indicate which specific recreation sites were surveyed.
2. Tree locations should be accurately described on the Tree Risk Assessment Form using GPS coordinates.
3. Risk rating of a tree is determined by Target and Defect:

	Definition	Values
Target	Target rating is a combination of the likelihood that a potential target will be hit (assuming the tree fails) and the value of the target.	Potential targets are assigned values of 1 or 2.
Defect	A defect rating is an estimation of the likelihood that a tree will fail based on available indicators.	Defects are assigned values of 0 – 3.

4. Height to diameter ratio is the ratio of the tree height to the trunk diameter at breast height (DBH). The same units should be used for both measurements, so DBH is typically converted from inches to feet.
5. Severe stem decay signs include any fruiting bodies or conks of Indian paint fungus (*Echinodontium tinctorium*), red belt fungus (*Fomitopsis schrenkii*), pouch fungus (*Cryptoporus volvatus*), or any stem decay fungus on white fir or cottonwood; more than one false tinder conk (*Phellinus tremulae*) on aspen or one false tinder conk in association with cracking, cavities, or other major structural defect; or more than two conks of red ring rot (*Porodaedalea pini*). See Tree Risk Assessment and Hazard Tree Mitigation in the Southwest Region for a detailed description of these stem decay fungi.
6. Moderate stem decay signs include one or two conks of red ring rot (*Porodaedalea pini*), one false tinder conk (*Phellinus tremulae*) unassociated with other defects, and conks of any other species not previously mentioned here or in the description of severe stem decay signs above. See Tree Risk Assessment and Hazard Tree Mitigation in the Southwest Region for a detailed description of these stem decay fungi.
7. More than one type of potential target or defect may be identified and checked for any tree. If identified, these defects will inform the land manager of the risk rating following mitigation of highest defect.
8. Calculate risk rating by multiplying target value and hazard value of the worst defect. Removal of highest rated trees for each target category or other mitigation action is recommended.

Possible Risk Ratings (Target × Worst Defect = Risk Rating):

Higher occupancy targets (e.g., picnic tables): 6 = highest, 4, 2 = lowest
Lower occupancy targets (e.g., roadways): 3 = highest, 2, 1 = lowest

For more information contact:

USDA Forest Service
Southwestern Region
Forest Health
333 Broadway Blvd., SE
Albuquerque, NM 87102

Or visit the Southwestern Region's website for tree risk management:

http://www.fs.usda.gov/goto/r3/treerisk

United States
Department of
Agriculture

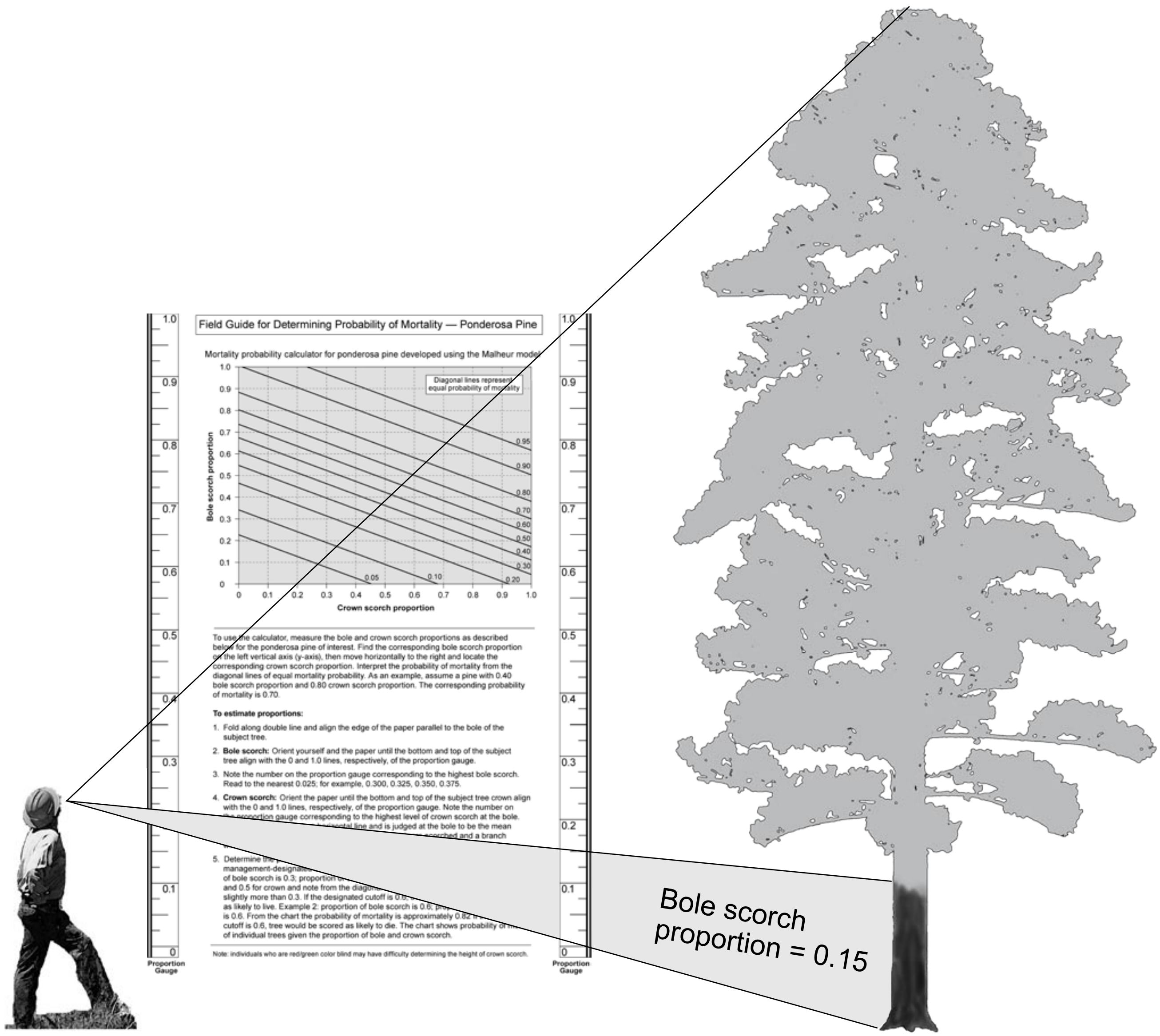
Forest Service

Pacific Northwest
Research Station

General Technical
Report
PNW-GTR-769
October 2008

A Field Guide to Predict Delayed Mortality of Fire-Damaged Ponderosa Pine: Application and Validation of the Malheur Model

Walter G. Thies, Douglas J. Westlind, Mark Loewen,
and Greg Brenner



Authors

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Abstract

Thies, Walter G.; Westlind, Douglas J.; Loewen, Mark; Brenner, Greg. 2008. A field guide to predict delayed mortality of fire-damaged ponderosa pine: application and validation of the Malheur model. Gen. Tech. Rep. PNW-GTR-769. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 16 p.

The Malheur model for fire-caused delayed mortality is presented as an easily interpreted graph (mortality-probability calculator) as part of a one-page field guide that allows the user to determine postfire probability of mortality for ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.). Following both prescribed burns and wildfires, managers need the ability to predict the mortality of individual ponderosa pine trees based on burn damage. The model was developed from fire-caused delayed mortality observed for 4 years postburn in a replicated study of 12 burn units and 6 nonburned units near Burns, Oregon. During the fourth year, the percentage of mortality on burned units was not statistically different from that on nonburned units. Here we report validation data from 3,237 ponderosa pines in 10 additional burns, observed for 3 years postburn, from the southern Blue Mountains and northern California that indicate a good fit between mortality predicted by the Malheur model and observed mortality. Tear-out copies of the field guide on water proof paper are provided.

Keywords: Blue Mountains, fire, ponderosa pine, big trees, delayed mortality.

Introduction

The Malheur model is a two-variable model developed from data collected following prescribed burns on the Malheur National Forest near Burns, Oregon (Thies et al. 2005, 2006). Fire-caused delayed mortality of ponderosa pines (*Pinus ponderosa* Dougl. ex Laws.) was surveyed annually for 4 years postburn. During the 4th year, the percentage of mortality on burned units was not statistically different from that on nonburned units. In the subsequent 6 years postburn (for a total of 10 years), the percentage of mortality on burned units remained at a low level similar to that on nonburned units. The model was used to generate a graph called the "mortality-probability-calculator" or "the calculator." The calculator allows a user to quickly determine the probability of mortality of fire-damaged ponderosa pine. Because the model predicts the probability of mortality for individual trees based on surface damage that reflects underlying physiological damage, it is valid for trees damaged by either prescribed fire or wildfire.

Prescribed burning and wildland fire are being used as tools to achieve specific management objectives in western interior forests of the United States. Following a burn, managers need the ability to predict the mortality of individual trees. Mortality is evaluated to determine the success of burning prescriptions to achieve such management objectives as postfire stocking levels and to improve future prescriptions, and for all fires to better plan postfire activities such as hazard tree removal and restoration of wildlife habitat and watershed quality. Postfire mortality predictions need to be based on easily observable morphological and burn-damage characteristics that can be quickly assessed in the field. The Malheur model meets these criteria for ponderosa pine. Details of the model development and the study it was based on are published elsewhere (Thies et al. 2005, 2006).

We present the Malheur model here in graph form as a two-factor mortality-probability calculator, and describe its use in a one-page field guide (app. 1) along with a list of cautions. Tear-out copies of the field guide are provided at the back of this GTR. In addition, a test of the efficacy of this model using data from 10 validation stands from the south end of the Blue Mountains in eastern Oregon and the east side of the Cascade Range in northern California is provided (app. 2). The 10 validation stands were not the same as those used for model development (fig. 1).

Postfire mortality predictions need to be based on easily observable morphological and burn-damage characteristics that can be quickly assessed in the field. The Malheur model meets these criteria for ponderosa pine.

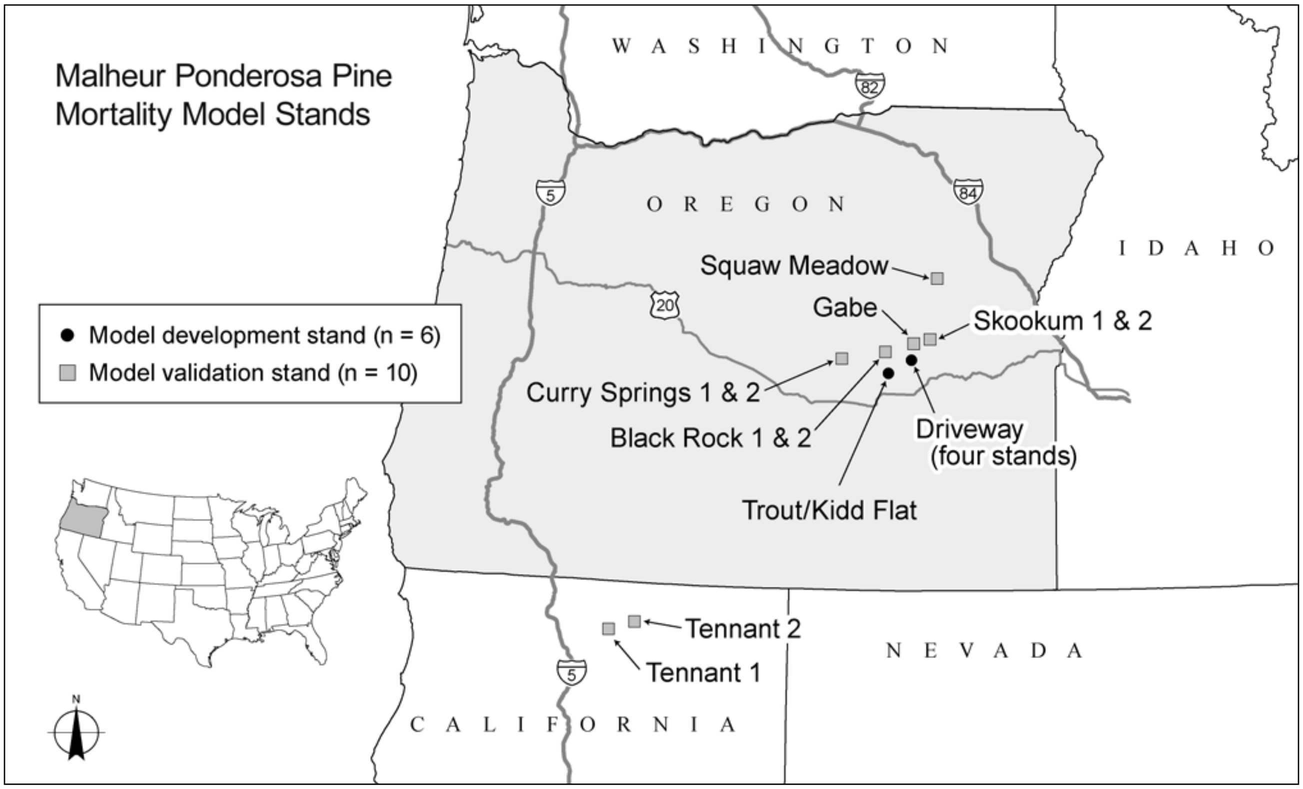

Figure 1—Location of stands used to collect Malheur model development and validation data.

Using the Mortality-Probability Calculator

A tree is evaluated by first measuring the proportion of both bole and crown scorch. **Bole scorch proportion** is the maximum bole scorch (blackened) height as a proportion of total tree height (fig. 2). **Crown scorch proportion** is the length of the scorched (scorched or consumed needles) portion of the crown as a proportion of the total crown (fig. 2). The crown base is taken as the lower height of live crown (whorl of three or more live branches) as it existed prefire. The layer of scorched crown is often asymmetrical. The height of the scorched crown is taken as the average height for that layer measured at the bole. The proportion can be calculated by using heights measured with an instrument, such as a laser rangefinder with inclinometer or hand-held clinometer, or determined directly by something as simple as the proportion gauge provided on the one-page field guide. The mortality-probability calculator is used by locating a tree's bole scorch proportion on the left vertical axis (the y-axis) and then moving horizontally to the right until reaching the crown scorch proportion. The value of the intercept point is the probability of mortality for that tree, determined from the nearest upper and lower diagonal lines of equal probability of mortality. The probability of mortality could be interpolated to the nearest 0.01 although that degree of precision may exceed most operational requirements.

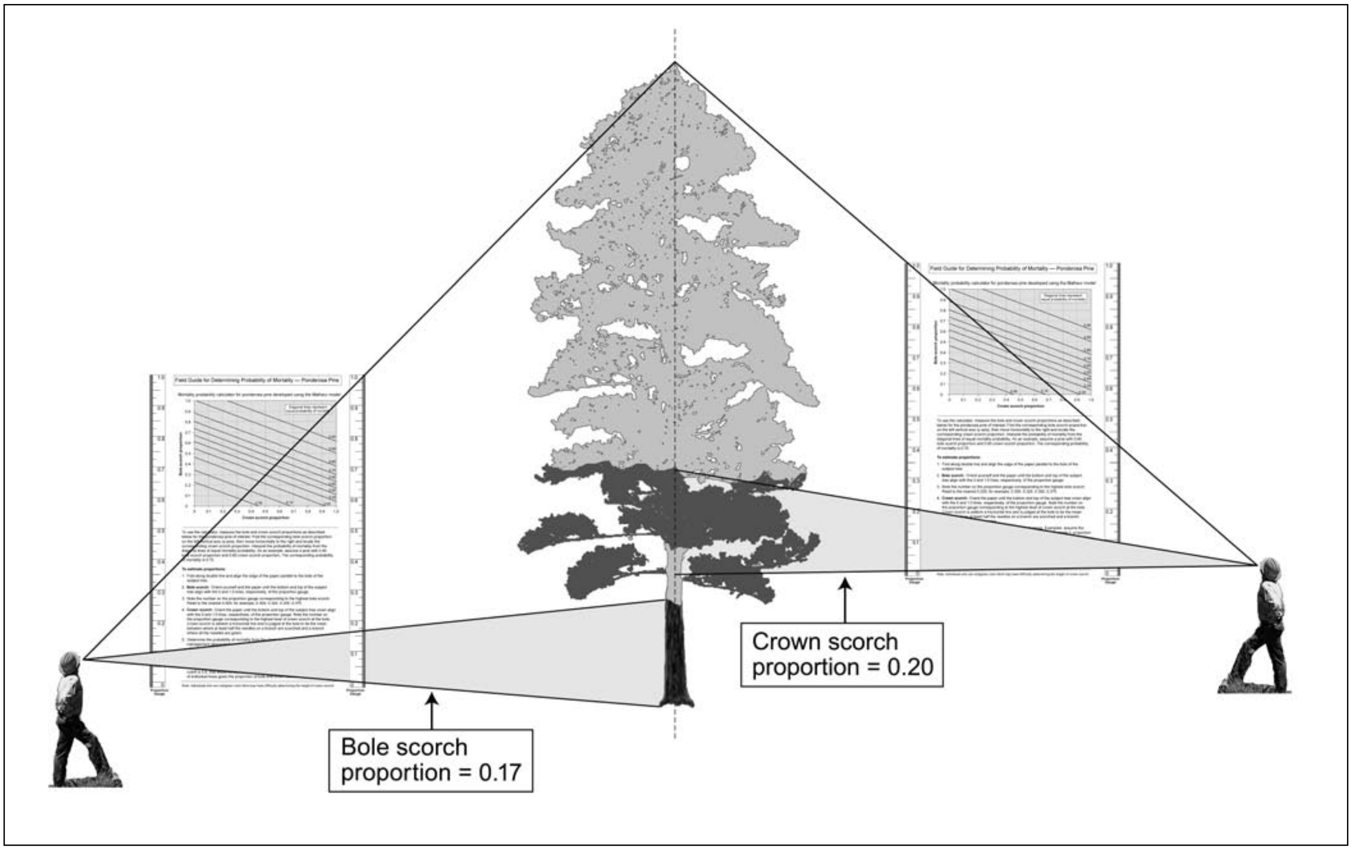

Figure 2—Measuring the proportions of bole scorch and crown scorch.

This two-variable mortality-probability calculator was derived for each 0.1 increment of probability of mortality from 0.0 to 1.0 (plus probabilities of 0.05 and 0.95) by holding the probability constant while proportion of crown scorch was increased by increments of 0.1 and using the model to solve for the corresponding proportion of bole scorch. The points were plotted resulting in straight lines representing points of equal probability of mortality.

Management Decision Tool

Use of the information from the Malheur model is determined by the objectives and needs of the land manager. Individual trees can be evaluated for probability of mortality, or a stand can be surveyed (sampled) and the proportion of trees projected to die can be determined. Probability of mortality for trees can be determined in the field using the calculator, or stem and crown scorch proportions can be recorded in the field and probability of mortality can be calculated in a spreadsheet.

This tool can be used to monitor (1) whether objectives were met for prescribed burns and wildland fire use, or (2) to determine if economical salvage opportunities exist after wildfire in consideration of other management objectives.

Individual tree example—

A management objective may require that all trees with a probability of mortality greater than 0.6 be marked for removal. Example 1: Proportion of bole scorch is determined to be 0.3; proportion of crown scorch is determined to be 0.5. Enter the calculator at 0.3 for bole scorch and 0.5 for crown scorch and find the intercept point. Note from the diagonal lines that the probability of mortality is slightly more than 0.3. If the designated probability limit is 0.6, the example tree would not be marked.

Example 2: Proportion of bole scorch is 0.6; proportion of crown scorch is 0.6. Enter the calculator at 0.6 for bole scorch and 0.6 for crown scorch and find the intercept point. Note from the diagonal lines that the probability of mortality is approximately 0.82. If the management designated mortality probability limit is 0.6, the tree would be marked for removal. The probability limit is established from management considerations.

If access to the subject trees makes frequent returns possible, the limit may be established high (e.g., 0.9) with a plan to return to remove additional trees that die. If the area is remote, thereby making frequent returns difficult, the limit may be established low (e.g., 0.3) with an intent to cut most of the trees that will likely die from the fire with a single entry.

Survey example—

A management objective may require that an estimate be made of the proportion of trees in a stand that will die. Perhaps the manager needs to learn at an early date the success of a particular prescription or to evaluate the need to replant. It is important that sample trees be randomly selected and representative of the stand or the portion of the stand of interest. Each sample tree would be evaluated and its probability of mortality recorded. A mean of the probabilities will be an estimate of the proportion of the trees in the stand that can be expected to die. For example, assume that 10 trees are representative and randomly selected from an area of interest and they have the following probabilities of mortality: 0.40, 0, 0, 0.55, 0, 0, 1.0, 0, 0.65, and 0.55. The total is 3.15; the proportion of trees likely to die in the stand is 3.15/10 or 0.315. Although the sample size in this example is unrealistically small, it illustrates the math involved.

Cautions

Every model must be used with caution to ensure that the sample population being tested is within the limits of the data used to develop the model. The following considerations are provided for the Malheur model:

1. Evaluate only ponderosa pine. Although results for other species may appear to conform to the results for ponderosa pine, it is unlikely that such is the case. Additional testing would be required to adjust the model for other species.
2. Sample within the geographic area of model development or where validation data from representative stands have been tested and results from the model have been shown to be a good fit to the observed data. (Note: At this writing the successfully tested geographic area of inference for the Malheur model ranges from the southern Blue Mountains of eastern Oregon south into northern California (app. 1, fig. 2).
3. Obtain the most accurate measurement possible to determine the bole and crown scorch proportions consistent with management objectives. Avoid ocular estimates as they will likely differ by observer and thus not yield consistent results.
4. The model provides a probability of mortality for a given tree and not an absolute indication that a tree will live or die. A probability of 0.6 means that if 1,000 trees have crown and bole scorch proportions that fall on the 0.6 line of probability, about 600 of them can be expected to die. All trees with a bole and crown scorch proportion that places them above the 0.6 probability line have a greater than 0.6 probability of mortality.
5. Because the model provides a probability, some trees predicted to live will die and some that are predicted to die will live. This was observed in stands used for both model development and validation. With or without fire, a few trees are likely to die in a stand each year because of other natural processes such as insects, disease, or limited resources. Additionally, a few trees with crown or bole scorch proportion equal to 1.0 will survive. Because of these anomalies, the model predicts a probability of mortality within the range from 0.011 to 0.972, rather than 0.0 to 1.0. The Malheur model will predict fire-caused mortality close to what would be observed in the next 3 years if the stand were undisturbed; however, the stands are biological systems and some small variation from the predicted mortality should be expected.

The model provides a probability of mortality and not an absolute indication that a tree will live or die.

6. The model predicts probability of mortality based on damage to individual trees and is not related to fire type or season of the burn. Data used to develop the model were collected from areas of prescribed burns; however, the sample trees encompassed the full range of burn-induced-damage from mild heat exposure and no visible damage to extreme burn damage with no chance of recovery. To access the full range of responses in these stands, data were collected from both spring and fall burns. The tested explanatory variables represented tree morphology, fire damage, and season of burn. After accounting for the fire damage variables, there was no indication of a difference in mortality between fall and spring burns. This was interpreted to mean that trees with similar degrees of damage from either burn season would have about the same probability of delayed mortality. We concluded that the mortality is related to the damage inflicted on each tree rather than the season as it relates to the physiological state of the trees. Because mortality is related to the damage inflicted, the type of fire is not important, and this model, although developed with data from prescribed burns, will work equally well with trees burned by a wildfire. One of the fires in the validation data set reported in appendix 1 was a prescribed burn that escaped and burned the stand as a wildfire. The data from that fire fit the Malheur model well and supports use of the model on trees damaged by wildfire.

Acknowledgments

Creation of the Malheur model has taken a sustained effort from 1996 through 2008 by many individuals through a variety of funding channels. The authors thank the Malheur National Forest, the Emigrant Creek Ranger District, and the Burns Interagency Fire Zone for their support throughout this effort. Without their constant and unselfish support this project would not have been possible. Fieldwork was conducted with funds provided by Forest Health Protection of the U.S. Department of Agriculture, Forest Service, through the Special Technology Development Program, the Pacific Northwest Research Station, and the Joint Fire Sciences Program. Special thanks to Mike Dubrasich of Forest Analytics of Lebanon, Oregon, for statistical review of the manuscript and to Karen Esterholdt for editing the manuscript. We also thank Paul Anderson, Erik Berg, Kenneth Higle, and Rick Kelsey for review and helpful comments during manuscript preparation.

English Equivalents

When you know	Multiply by	To find
Centimeters (cm)	0.394	Inches
Meters (m)	3.28	Feet

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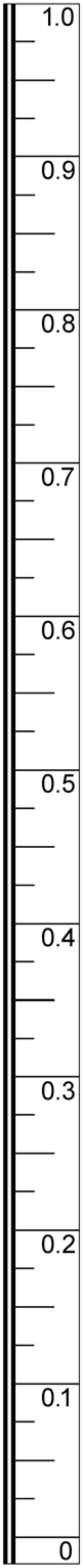
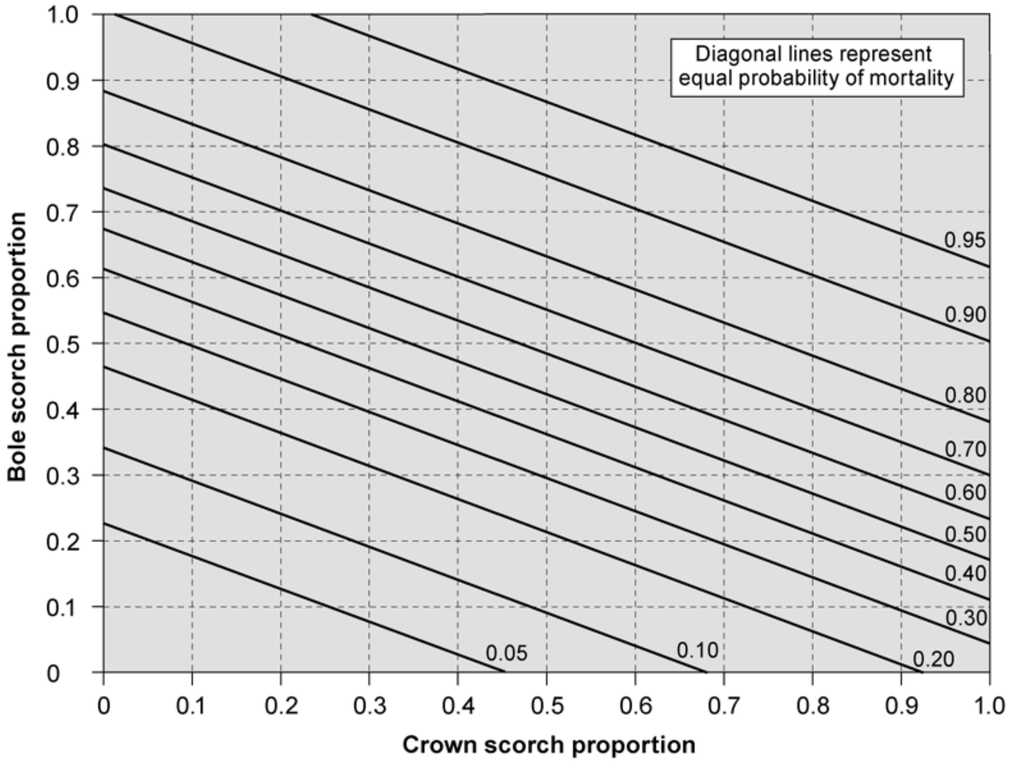


Proportion Gauge

Field Guide for Determining Probability of Mortality — Ponderosa Pine

Mortality probability calculator for ponderosa pine developed using the Malheur model

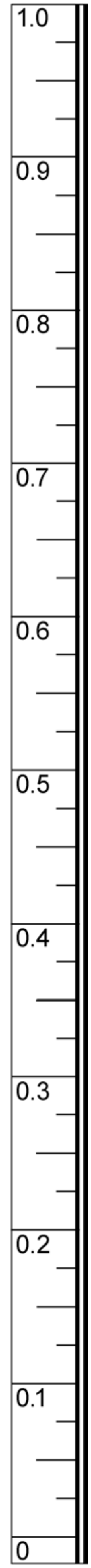


To use the calculator, measure the bole and crown scorch proportions as described below for the ponderosa pine of interest. Find the corresponding bole scorch proportion on the left vertical axis (y-axis), then move horizontally to the right and locate the corresponding crown scorch proportion. Interpret the probability of mortality from the diagonal lines of equal mortality probability. As an example, assume a pine with 0.40 bole scorch proportion and 0.80 crown scorch proportion. The corresponding probability of mortality is 0.70.

To estimate proportions:

1. Fold along double line and align the edge of the paper parallel to the bole of the subject tree.
2. **Bole scorch:** Orient yourself and the paper until the bottom and top of the subject tree align with the 0 and 1.0 lines, respectively, of the proportion gauge.
3. Note the number on the proportion gauge corresponding to the highest bole scorch. Read to the nearest 0.025; for example, 0.300, 0.325, 0.350, 0.375.
4. **Crown scorch:** Orient the paper until the bottom and top of the subject tree crown align with the 0 and 1.0 lines, respectively, of the proportion gauge. Note the number on the proportion gauge corresponding to the highest level of crown scorch at the bole. Crown scorch is seldom a horizontal line and is judged at the bole to be the mean between where at least half the needles on a branch are scorched and a branch where all the needles are green.
5. Determine the probability of mortality from the chart above. Examples: assume the management-designated cutoff for probability of mortality is 0.6. Example 1: proportion of bole scorch is 0.3; proportion of crown scorch is 0.5. Enter the chart at 0.3 for bole and 0.5 for crown and note from the diagonal lines that the probability of mortality is slightly more than 0.3. If the designated cutoff is 0.6, the example tree would be scored as likely to live. Example 2: proportion of bole scorch is 0.6; proportion of crown scorch is 0.6. From the chart the probability of mortality is approximately 0.82 if the designated cutoff is 0.6, tree would be scored as likely to die. The chart shows probability of mortality of individual trees given the proportion of bole and crown scorch.

Note: individuals who are red/green color blind may have difficulty determining the height of crown scorch.



Proportion Gauge

Appendix 2: Malheur Model Validation

Introduction

The Malheur two-factor model, presented here in graph form as the mortality-probability calculator, predicted 96.4 percent of the observed mortality caused by the prescribed burns used for model development (Thies et al. 2006). But a model remains a hypothesis until it is validated by using data unrelated to the developmental data. We report here the results of an effort to validate the Malheur model in a limited area by evaluating sample trees in burns in 10 ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) stands in the southern Blue Mountains of eastern Oregon and the east side of the Cascade Range in northern California. The 10 validation burns are in different stands than the 12 burns used to collect data for model development.

Methods

Validation stands (fig. 1, table 1) were identified and data collection begun within a month following their respective burns from fall 2002 through fall 2004. Stands were selected according to accessibility of a prescribed burn, available cooperation from Forest Service ranger districts, and geographic distribution of sites. The number of trees tagged in each stand was dependent on staff time and funding.

Within each stand, a starting point was selected near an access road in a portion of the stand typical of that burn. A random starting azimuth was selected within the azimuth range that would encompass the range of fire damage observed. If the first transect was not long enough to provide adequate numbers of trees, the crew

Table 1—Stand summary for validation stands

Stand name	Latitude/longitude	Area	Elevation	Burn date	Mean d.b.h.[a]	Mean height
		Hectares	*Meters*		*Centimeters (range)*	*Meters*
Black Rock 1	43.88N, 118.86W	60	1595	Fall 2004	27.8 (8.9–85.1)	13.9
Black Rock 2	43.95N, 118.82W	90	1650	Fall 2004	24.1 (7.6–96.5)	12.2
Curry Springs 1	43.93N, 119.63W	30	1685	Fall 2002	37.8 (12.2–101.9)	19.3
Curry Springs 2	43.91N, 119.61W	30	1670	Spring 2003	41.2 (8.6–95.0)	20.7
Gabe	44.11N, 118.75W	55	1585	Fall 2004	43.2 (10.4–95.0)	21.3
Skookum 1	44.10N, 118.41W	30	1645	Fall 2002	42.7 (15.7–78.7)	21.3
Skookum 2	44.12N, 118.42W	30	1650	Spring 2003	43.6 (8.9–104.6)	21.2
Squaw Meadow	44.50N, 118.43W	90	1760	Fall 2004	24.6 (7.6–76.5)	13.8
Tennant 1	41.58N, 121.93W	240	1240	Fall 2004	39.1 (7.9–192.0)	18.3
Tennant 2	41.65N, 121.67W	45	1480	Fall 2004	34.9 (8.6–208.3)	16.8

[a] d.b.h. = diameter at breast height.

offset 50 to 100 m within the burn and continued along the back azimuth. The strip sampled extended 5 m to either side of the transect centerline. All standing ponderosa pine greater than 7.5 cm diameter breast high (d.b.h.) within the sampling strip were tagged. A numbered aluminum tag was placed on each tree, in numerical order, at breast height toward the transect centerline.

Each tagged tree was evaluated and marked at the time of transect establishment as either alive (if the tree had some green needles) or dead (if all needles were scorched or discolored owing to heat from the fire). Dead trees were categorized by time of death as preburn mortality (based on bark condition, presence of decay, and lack of needles and fine twigs), immediate mortality (alive at the time of the burn but dead when tagged), and delayed mortality (found dead in later exams, table 2).

Table 2—Summary of tree means sampled from the 10 validation stands

Stand name	Trees alive at burn	Trees dead after 3 years	Mortality
			Percent
Black Rock 1	298	42	14.1
Black Rock 2	294	35	11.9
Curry Springs 1	121	12	10.0
Curry Springs 2	249	24	9.6
Gabe	300	17	5.7
Skookum 1	289	35	12.1
Skookum 2	296	14	4.7
Squaw Meadow	300	80	26.7
Tennant 1	731	91	12.5
Tennant 2[a]	359	71	19.8

[a] The Tennant 2 burn began as a prescribed burn; however, the fires got out of control and created a wildfire situation. Sampling on this unit was done in the area of the wildfire using the same protocol as for other validation units.

At the time of tagging, morphological variables were recorded for each tagged tree. The d.b.h. of each tagged tree was measured to the nearest 0.25 cm on the uphill side of the tree at 1.37 m above mineral soil, and the height was measured to the nearest 3.0 cm with a laser rangefinder with inclinometer (table 1). Two measures of fire-caused damage were recorded for each tree: crown scorch proportion and bole scorch proportion.

Crown scorch proportion is the proportion of damaged crown length based on scorched or consumed needles. The total crown length is the distance from the tree tip to the lower height (whorl of three or more live branches) of live crown as it existed prefire. Immediately postfire, crowns that are alive but damaged show two layers: an upper green layer and a lower brown layer of scorched or consumed needles. Damage layers often were asymmetrical. The scorch height was taken as the average height for that layer measured at the bole. Heights were measured to the nearest 3.0 cm with a laser rangefinder with inclinometer. Crown scorch proportion as a measure of crown damage has been used by others and allowed reproducible results with a minimum of training of field crews (Thies et al. 2006).

Bole scorch proportion is the maximum bole scorch height as a proportion of total tree height. Bole scorch is the distance from mineral soil to the highest point of bole blackening measured to the nearest 15 cm.

Only those tagged trees living at the time of the prescribed burns were included in this validation evaluation. Each fall, starting with the first growing season after the burn, sample transects were revisited and delayed mortality recorded; trees without any green needles, and not previously marked as dead, were recorded as having died that growing season.

We tested the agreement between the mortality predicted by the Malheur model and the mortality observed 3 years postburn of tagged trees from the 10 validation stands using the Hosmer-Lemeshow goodness of fit test, the receiver operating characteristic (ROC) scores, and percentage of correctly classified trees. The Hosmer-Lemeshow goodness of fit test was used to evaluate the fit of the full and reduced (Malheur) models to the development data (Thies et al. 2006) and the Malheur model to the validation data. The data were first partitioned into groups based on the predicted probability of mortality (table 3). We classified the mortality probabilities from 0.0 to 1.0 into 10 groups identified by the midpoints (0.5 to 0.95). The sum of the predicted probability of mortality of all trees in a decile was used as the projected number of trees expected to die in that class. The actual observed status of the trees 3 years postburn (alive, dead) was recorded for each decile from the observed dead trees. If the Malheur model is accurate, then the projected

Table 3—Calculated mortality and observed mortality for the Malheur model across the range of probability of mortality classes

	Probability-of-mortality classes, by midpoint percentage										
Data set	**5**	**15**	**25**	**35**	**45**	**55**	**65**	**75**	**85**	**95**	**Total**
						Number					
Validation data set:											
Total trees in class—	2,380	304	151	94	65	58	52	44	37	52	3,237
Projected dead	75	44	37	33	29	32	33	33	32	50	398
Observed dead	72	31	24	34	33	36	39	37	34	46	386
Development data set:[a]											
Total trees in class—[a]	2,315	280	162	130	153	99	82	78	59	57	3,415
Projected dead[a]	64	41	40	46	69	54	53	59	50	54	530
Observed dead[a]	80	44	29	43	60	67	56	61	55	55	550

[a] From Thies et al. 2006.

number of dead trees should be close to the observed number of dead trees. The Hosmer-Lemeshow test statistic (HL) was calculated by comparing the observed and expected frequencies of the dead trees in the decile groups. The test statistic has a chi-square distribution with a desirable outcome of nonsignificance ($P > 0.05$), thereby indicating that the model prediction does not significantly differ from the observed data (Hosmer and Lemeshow 2000, van Mantgem et al. 2003). The ROC analysis paralleled that done by Saveland and Neuenschwander (1990) to evaluate models of tree mortality following fire damage. The ROC curve is a plot of the sensitivity (y-axis) and 1-specificity (x-axis) over all possible mortality probability cutoff values. Sensitivity is the ability to correctly predict a tree to die (proportion of tree deaths that were predicted). Specificity is the ability to correctly predict a tree to live (proportion of surviving trees that were predicted). The area under the curve is a measure of the ability of the model to discriminate between dead and alive trees. The ROC area values range from 0 to 1.0. A value for the area under the curve of 1.0 indicates a perfect model, which would yield no false positives. The ROC values ≥0.7 are acceptable; values ≥0.9 are indicative of outstanding discrimination (Hosmer and Lemeshow 2000).

Results and Discussion

Within the 10 validation stands, 3,237 ponderosa pine were evaluated. The Malheur model had a good fit to the data from the validation stands (table 3): HL = 10.31, d.f. = 8, $P = 0.244$. The Malheur model predicted a total mortality of 398 trees based on the two measured variables of fire damage. Three growing seasons postburn the actual observed mortality was 386 trees, a difference of 3.1 percent of the predicted mortality from the observed mortality. Table 3 illustrates the fit of the model across the range of probability-of-mortality classes. These results closely parallel the Malheur model fit to the data from the 3,415 ponderosa pine in the model development data set (Thies et al. 2006).

The ROC curve is presented as figure 3; the area under the curve is 0.8815 (standard error 0.01134; 95-percent confidence interval of 0.8593 to 0.9038; $P < 0.0001$) indicating a good fit between the predicted and the observed outcomes.

We used classification tables as a supplemental measure of model fit. For our analyses, 0.5 was selected a priori as the decision criterion. That is, trees with predicted probability of mortality, ≥0.5 are predicted dead. We used this cutoff criterion because we had no reason for selecting otherwise. A cutoff of 0.5 was used previously for fire-killed ponderosa pine (Regelbrugge and Conard 1993), for fire-killed Douglas-fir (Ryan et al. 1988), and is considered the most common cutoff used in a variety of applications (Hosmer and Lemeshow 2000). A classification

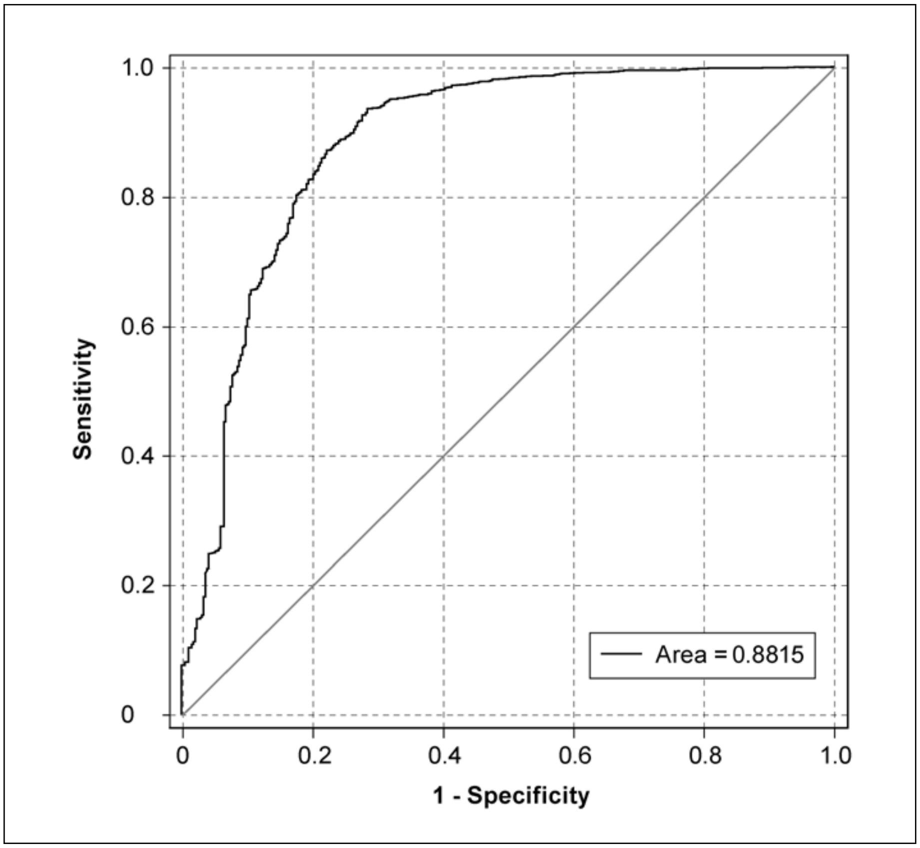


Figure 3—The ROC curve representing the relationship between the Malheur model and the validation data with the area under the curve being equal to 0.8815 (n = 3,237). Sensitivity is the false positive and specificity is the false negative.

table was prepared for the validation data set (table 4). The overall rate of correct classification was 92.4 percent. The overall rates of correctly predicting mortality of individual trees was 79.0 percent.

The Malheur model fits the available data for wildfire-like conditions. One of the stands included in the validation set (Tennant 2) was a prescribed fire that

Table 4—Classification table of the validation data set based on the Malheur model logistic regression using a cutoff of 0.5 probability of mortality

	Observed		
Predicted	**Alive**	**Dead**	**Total**
Alive P(m) <0.5	2,800	194	2,994
Dead P(m) >0.5	51	192	243
Total	2,851	386	3,237

Overall rate of correct classification = [(2,800 + 192)/3,237] × 100 = 92.4 percent.
Overall rate of correctly predicting mortality = 192/243 × 100 = 79.0 percent.

escaped and burned much of the unit as a wildfire. The sample transects were placed in the wildfire portion of the stand, and the data were collected from sample trees (n = 359) using the same protocols followed for the other nine stands from which validation data were collected. The area under the ROC curve for Tennant 2 is 0.8925 (standard error 0.02379; 95-percent confidence interval of 0.8459 to 0.9391; $P < 0.0001$) indicating a good fit between the predicted and the observed outcomes. A classification table was prepared for the Tennant 2 data (table 5). The

Table 5—Classification table of the Tennant 2 data set based on the Malheur model logistic regression using a cutoff of 0.5 probability of mortality

	Observed		
Predicted	**Alive**	**Dead**	**Total**
Alive *P*(m) <0.5	272	25	297
Dead *P*(m) >0.5	16	46	62
Total	288	71	359

Overall rate of correct classification = [(272 + 46)/359] × 100 = 88.6 percent.
Overall rate of correctly predicting mortality = 46/72 × 100 = 74.2 percent.

overall rate of correct classification was 88.6 percent. The overall rate of correctly predicting mortality was 74.2 percent. Similar results were observed for the nearby (fig. 2) Tennant 1 successfully conducted prescribed burn. The Tennant 1 unit (n = 731) has an area under the ROC curve of 0.9378 (standard error 0.0125; 95-percent confidence interval of 0.9132 to 0.9623; $P < 0.0001$. A classification table was prepared for the Tennant 1 data (table 6). The overall rate of correct classification was 93.6 percent, and the overall rate of correctly predicting mortality was 83.3 percent (table 6). We consider this evidence that individual trees respond to their fire-induced damage and trees with similar damage characteristics will have a similar probability of mortality whether the damage is induced by a prescribed fire or a wildfire.

The Malheur model can be used to determine probability of fire-caused delayed mortality in individual trees regardless of whether the fire is a prescribed fire or a wildfire.

Table 6—Classification table of the Tennant 1 data set based on the Malheur model logistic regression using a cutoff of 0.5 probability of mortality

	Observed		
Predicted	**Alive**	**Dead**	**Total**
Alive *P*(m) <0.5	629	36	665
Dead *P*(m) >0.5	11	55	66
Total	640	91	736

Overall rate of correct classification = [(629 + 55)/731] × 100 = 93.6 percent.
Overall rate of correctly predicting mortality = 55/66 × 100 = 83.3 percent.

The Malheur model did well in predicting the delayed mortality of “big” ponderosa pine (>53.3 cm). These big trees currently are being protected in U.S. Forest Service Region 6 and are of special concern to managers. Both the development and the validation stands contained big ponderosa pine. The validation stands contained 522 big trees of which 23 died; the Malheur model predicted that 25 big trees would die. The largest tree in the validation data set was 208.3 cm dbh. The model development data set contained 213 big trees of which 15 died. A classification table was prepared for the combined big tree data (table 7). The overall rate of correct classification and the overall rate of correctly predicting mortality were 95.2 percent and 66.6 percent, respectively. The big trees were not given any special treatment or protection during either the development or the validation burns (n = 22 burns) yet the mortality rate of big trees was 5.2 percent (n = 735) while the mortality rate of all sample trees was 14 percent (n = 6,652).

The Malheur model can be used to determine the probability of fire-caused mortality of big ponderosa pine.

Table 7—Classification table for large ponderosa pine (over 53.3 cm d.b.h.) based on the Malheur model logistic regression using a cutoff of 0.5 probability of mortality

	Observed		
Predicted	**Alive**	**Dead**	**Total**
Alive *P*(m) <0.5	694	32	726
Dead *P*(m) >0.5	3	6	9
Total	697	38	735

Overall rate of correct classification = [(694 + 6)/735] × 100 = 95.2 percent.
Overall rate of correctly predicting mortality = 6/9 × 100 = 66.6 percent.
There were 735 big (over 53.3 cm d.b.h) trees in the original and the validation data sets, of which 38 died; the two-factor model predicted 33.5 would die.

Ponderosa pine that have had all needles consumed or scorched but have not had significant bark consumption have a small but real probability of survival. In the validation data set (n = 3,237), 162 trees had all needles consumed or scorched; of these, 95 regreened (new needles formed) within a season of the burn, and 14 were still living 3 years later. In the development data set, 278 trees had all needles consumed or scorched; of these, 30 regreened within a season and 10 were still living 8 years later.

Conclusions

1. There is good agreement between the delayed mortality predicted by the Malheur model and the mortality observed 3 years following the burn in the 10 validation stands.
2. The geographic area of inference for using the Malheur model has been expanded north of the development stands and south into northern California.
3. The Malheur model can be used to determine probability of fire-caused delayed mortality in individual trees regardless of whether the fire is a prescribed fire or a wildfire.
4. The Malheur model can be used to determine the probability of fire-caused mortality of big ponderosa pine.
5. The observed proportion of big ponderosa pine killed by fire was about 5 percent.

Epilogue

An additional validation study was begun in summer 2007 to broadly sample burns in eastern Washington and Oregon. The sample burns are expected to include equal numbers of wildfires and prescribed burns. Each ponderosa pine stand will be evaluated by using both conventional height-measurement instruments as well as the simple proportional system shown on the field guide.

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