TREE NOTES

CALIFORNIA DEPARTMENT OF FORESTRY AND FIRE PROTECTION

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Survival of Fire-Injured Conifers in California

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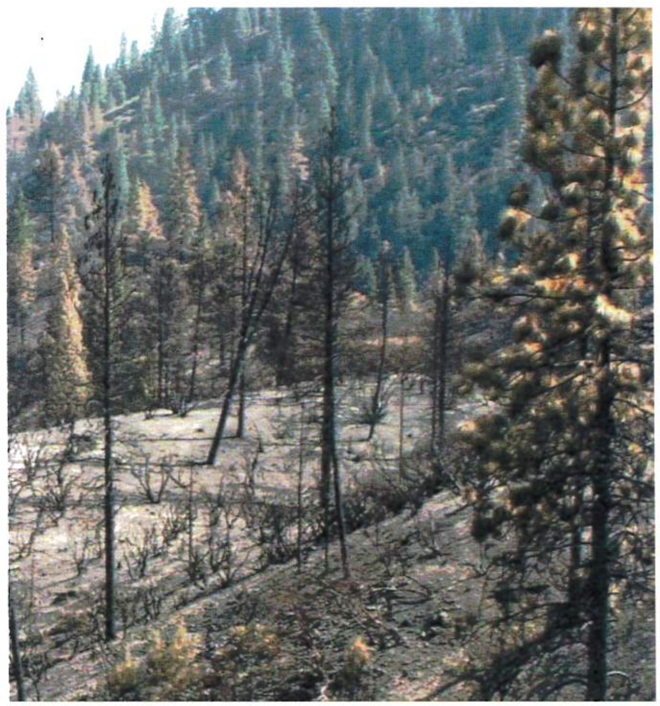
The intensity of wildfire and the injury it causes to trees varies considerably across a landscape. Conifers are killed outright when all foliage in the crown is consumed by flames or killed by extreme heat. Trees may also sustain lesser injuries to the crown, stem and roots and survive. These trees, however, may die prematurely if the injuries are severe. How well a tree survives fire injury is influenced by a variety of factors, including:

- Tree species
- Tree age, size, and vigor
- Extent and location of injury on the tree



Fire impacts trees by heating and killing tissues such as foliage, buds, inner bark and cambium. In extreme cases, foliage, twigs, bark and decayed wood are consumed. Even though severe fire intensity can kill trees directly, the wood in larger sound roots, branches and trunks is typically not degraded until pest organisms invade the tree.

Fire-injured trees may have a reduced probability of survival depending on the level of injury. Most tree mortality takes place within five years post-fire, with the highest levels occurring within the first two years. Fire injuries can also have longer lasting impacts on tree health and may contribute to mortality beyond this time frame, such as if root disease or decay gains entrance to the tree as a result of the injury.

Insects in the families Buprestidae, Cerambycidae, and Siricidae are principal colonizers of fire-killed or severely fire-injured trees. Some of these insects are attracted by smoke and will lay eggs on trees that are still smoldering; because they colonize trees that are dead or dying from fire injury, they are not considered a direct threat to tree survival. Bark beetles (primarily *Dendroctonus* species), in contrast, are more likely to colonize trees that are lightly to moderately fire injured and may kill some trees that might otherwise have survived. Bark beetle activity typically increases and may persist for several years in burned areas, but rarely spills over into healthy, uninjured trees or trees in adjacent unburned areas.

Pioneering research on estimating the survival of fire-injured trees in California was published by forest pathologist Willis Wagener (1961). Subsequent research has been conducted both in California and other parts of the western US that expanded upon and refined our understanding of tree survival (see references). While all of this information is valuable, it also has limitations and complexities that influence effective application by land managers. Using this research, the Forest Health Protection group within the USDA Forest Service has developed and tested guidelines for evaluating tree survival across a range of landscapes, tree species, and fire conditions in California. The report **Marking Guidelines for Fire-Injured Trees in California** (Smith and Cluck 2011) is the result.

This **Tree Note** does not attempt to duplicate the USFS Guidelines, but rather serves as an introduction to fire injury and tree survival, and presents a basic version of the Guidelines. Land managers desiring more information should consult the USFS Guidelines and other references.

MEASURING INJURY

For all conifer species studied, fire injury to the crown is the most important variable influencing survival. Another important variable is injury to the inner bark and cambium at the base of the main stem. Bark beetle attacks in response to injury can be an additional predictor of mortality. The USFS Guidelines include evaluation protocols that range from basic to complex. The basic level of evaluation requires an estimate of crown injury and stem diameter. Additional measures, such as cambial kill and bark beetle activity may improve predictions of survival. Because most fire-related mortality takes place within 5 years following the fire, this is the time frame for which survival estimates have been developed.

Crown Injury

Crown injury is defined as the percentage of the tree's pre-fire live crown (all branches supporting green needles) killed by fire. For most conifer species, this can be estimated by measuring the percentage of foliage that was consumed or killed by the fire. For ponderosa and Jeffrey pines, due to more fire resistant buds and twigs, the percentage of foliage killed is typically much greater than the percentage of crown killed. An accurate measurement of crown kill for ponderosa and Jeffrey pines usually requires waiting until new foliage is produced the following spring. If waiting to evaluate crown kill for ponderosa and Jeffrey pine is not practical, the Guidelines also provide a survival prediction based on fire-killed foliage alone (Table 1a), before the level of crown kill can be determined.

Obtaining a full view of the crown under good light conditions is important when estimating injury. Overcast skies and shade can make it difficult to distinguish green (live) from brown (dead) needles. Ideal lighting is direct sunlight coming from behind the observer with the sunlit crown viewed against a clear sky. Injury is often heavier on one side of the crown, so the best estimate takes this variation into account (Figure 1).

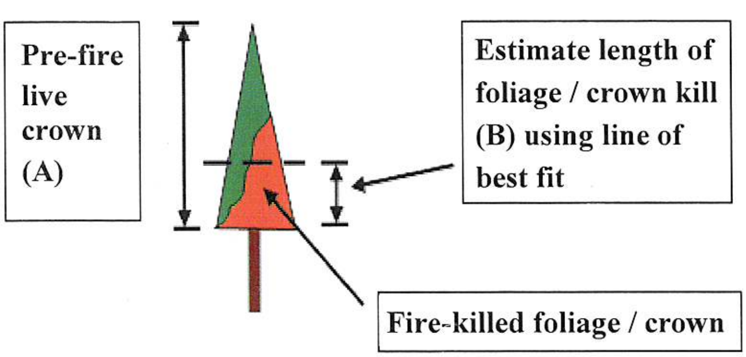


Figure 1.
Percentage of foliage or crown killed by fire = B/A x 100

Measurement of crown kill requires an estimate of the live crown before the fire occurred. The pre-fire live crown is defined as all branches with needles, both green (live) and brown (fire-killed), as well as any branches whose needles were consumed by the fire. If a branch has fine blackened twigs but no needles, the observer should assume it had needles before the fire. Over time, loss of fire-killed needles will reduce the ability to estimate the pre-fire live crown. Therefore, the appropriate timeframe for using the Guidelines is after the fire through fall of the following year (a 12- to 17-month post-fire timeframe). If an evaluation is done during the second growing season following the fire, be sure that the new year's (spring) growth is apparent before evaluating crown kill. Any branch with new growth is part of the live crown.

Cambial Injury

The vascular cambium is a cylinder of actively dividing cells within the stem that produces phloem (inner bark) to the outside and xylem (wood) to the inside. The outer, corky layer of bark helps prevent injury, but its ability to do so varies with tree species, age, and characteristics of the fire. If the cambium is killed, the adjacent phloem and xylem die and become non-functional. Cambium at the base of the tree's stem is particularly susceptible to injury. When the amount of cambium killed at the base of the stem is 25% of the circumference or less, this is likely to be inconsequential to tree survival. As this percentage increases, the loss of vascular tissues becomes critical and at some point the tree is effectively girdled. Non-lethal cambial wounds can be healed by the tree over time. Larger wounds provide an entryway to pathogens that cause root disease and wood decay, and may never heal completely.

Cambial kill at the base of a tree's stem can be roughly estimated by examining the outer bark. Assume the cambium is alive beneath portions of the bark that are not blackened. At the other extreme, assume the cambium is dead beneath bark that is completely blackened and eroded (consumed) to the point where its structure is no longer discernable. The bark may even be eroded and cracked to the point where the wood beneath is visible. Heavy pitch flow concentrated on a portion of the bark is also a good indication that the cambium beneath has been killed. When the condition of the outer bark falls between these extremes, i.e. the bark is blackened but has little or no pitching or loss of structure, it is best to inspect the cambium directly to determine its condition.

The protocol for directly estimating cambial kill is to use an axe to sample a small portion (about 1 square inch or less) of the inner bark / cambium at 4 equally spaced locations around the circumference of the stem, a few inches above ground line (Figure 2). Live inner bark and cambium is cream-colored and moist, often with a tinge of pink. Dead tissue dries and darkens with time and may be resinous. Brown, shrunken tissue is unequivocally dead. Cambial injury is rated as 0 to 4 based on the number of samples with dead cambium. For most trees, a cambial injury rating of 2 to 4 will increase the probability of mortality. Although the Guidelines do not require an evaluation of cambial injury, it is still a good idea to quickly inspect the lower stem for injuries that may significantly influence survival. A review of the Guidelines will help determine the value of assessing cambial injury to improve survival estimates.

Figure 2. Cambial sample

Non-lethal cambial injury can have a negative impact on tree health during and beyond the five years post-fire for which these guidelines apply. When wound-invading wood decay or root disease pathogens gain entrance to a tree, this can lead to hazardous conditions due to stem or root failure. While white and red firs are particularly prone to this, any tree with significant wounding has the potential to become a safety risk. Likewise, if a tree's vascular system has been significantly impaired by wounding and decay, the tree will have slower growth and may have a higher probability of dying, especially during periods of drought.

Insect Attack

While a variety of factors may contribute to tree mortality, a common feature of tree dieback and death is colonization of the cambial region by insects and associated microorganisms. In some instances, colonizing insects and fungi cause tissue death, while in other instances, the invaders are simply colonizing dying tissue. When colonization completely encircles the stem, this is a sure sign the tree is dead.

Recognizing successful colonization by insects can enable you to determine if a tree is dead or dying, regardless of crown and cambial injury. External evidence of bark beetle attack occurs in the form of pitch tubes, pitch streaming (which also occurs due to fire injury), pitch granules, and boring dust. Release of pitch is a defensive response of conifers and is a sign that the tree is successfully defending itself against beetle attack. "Dry" boring dust (i.e., with little or no pitch) in bark crevices indicates that tissues beneath are dead and being successfully colonized by insects. White dust is produced by ambrosia beetles that bore directly into the sapwood, while yellow-brown or red-brown dust is produced by bark beetles. Successful insect attack can be confirmed by cutting into the bark at or near spots where boring dust has accumulated and looking for live beetles (adults, eggs, or larvae) and their tunnels. When successful attacks encircle the stem, the tree is dying.

The red turpentine beetle (RTB) is one of the first bark beetles to attack fire-injured ponderosa, Jeffrey, and sugar pines. Its main flight period is in the spring, and this is typically when RTB becomes active in recently burned areas. RTB pitch tubes at the base of the stem can provide additional information for estimating tree survival.

Dead or dying trees (all foliage consumed or killed) will quickly be colonized by wood-boring insects and associated fungi that cause wood stain and decay. Evidence of colonization may not be apparent immediately after the fire but will increase over time as coarse woody shavings are expelled by developing beetle larvae.

<u>BASIC GUIDELINES</u> (Abbreviated form of the USFS Guidelines – Smith and Cluck 2011)

The Guidelines are based on probabilities, i.e. what is the likelihood that this tree will die from its fire injuries within 5 years? Table 1a uses percentage of foliage killed and Tables 1b to 7 use percentage of crown killed to determine probability of tree mortality, irrespective of cambial injury or insect attack. Measuring only foliage or crown kill is the quickest and easiest way to determine probability of mortality. Listed beneath some of the tables is information on how cambial injury and RTB pitch tubes modify the probability of mortality.

Little information exists on the impacts of fire injury on long-term tree health, but we know that such impacts occur. These impacts occur because the vascular system or structural integrity of the tree has been impaired. Disease organisms are often involved. How to address long-term impacts depends upon management goals for the property. Tree hazard needs to be addressed when there is a risk to life or property. Tree growth and longevity are important considerations for lands being managed for timber.

Tables for determining probability of mortality begin on the next page.

Tables 1a & b. Mortality of **Fire-Injured Ponderosa and Jeffrey pines** (based on Hood *et al.* 2010)

Table 1a. Evaluation made before the next growing season

*** Percentage of foliage killed by fire**

Probability the tree will die ⇨	30%	50%	70%
DBH (diameter of stem at breast height)			
10 to < 30"	70 *	80	90
30 to 40"	35	45	60
> 40"	15	30	40

* length of crown with dead (brown) + consumed foliage ÷ length of entire crown (all foliage) × 100

Modifications to Table 1a based on Cambial Injury Rating

trees 10 to < 30" DBH

- Rating of 0 or 1 reduces the probability of mortality by 20-30%
- Rating of 2 causes no change
- Rating of 3 or 4 increases the probability of mortality by 5-30%

trees ≥ 30" DBH

- Rating of 0 or 1 reduces the probability of mortality by 0-10%
- Rating of 2 increases the probability of mortality by 10%
- Rating of 3 or 4 increases the probability of mortality by 10-30%

For fires that occur before pine foliage has fully elongated (May and much of June): shoots and fire-scorched needles may continue to grow, producing brown needles with green bases (post-fire growth). When this occurs, consider portions of the crown with these needles as alive and utilize Table 1b to rate probability of mortality.

Table 1b. Evaluation made during the growing season following the fire (one winter has passed and the new year's growth is apparent; any branch with new growth is part of the live crown)

*** Percentage of live crown killed by fire**

Probability the tree will die ⇨	30%	50%	70%
DBH (diameter of stem at breast height)			
10 to < 30"	40 *	50	60
30 to 40"	10	25	40
> 40 to 50"	--	10	25

* length of killed crown (branches with only brown or consumed foliage) ÷ length of entire crown (all foliage) × 100

Modifications to Table 1b based on Cambial Injury Rating

trees 10 to < 30" DBH

- Rating of 0 or 1 reduces the probability of mortality by 10%
- Rating of 2 causes no change
- Rating of 3 or 4 increases the probability of mortality by 15-20%

trees ≥ 30" DBH

- Rating of 0 or 1 reduces the probability of mortality by 5-10%
- Rating of 2 causes no change
- Rating of 3 or 4 increases the probability of mortality by 5-10%

Red Turpentine Beetle

- When pitch tubes are absent, probability of mortality remains the same or decreases slightly (up to 10%)
- When pitch tubes are present on trees10 to < 30" DBH, probability of mortality increases slightly (up to 10%)
- When pitch tubes are present on trees ≥ 30" DBH, probability of mortality increases significantly (up to 40%)

Table 2. Mortality of **Fire-Injured Sugar Pine** (based on Hood *et al.* 2010)

* **Percentage of live crown killed by fire**

Probability the tree will die ⇨	**30%**	**50%**	**70%**
DBH (diameter of stem at breast height)			
10 to 60"	**40 ***	**50**	**60**

* length of killed crown (brown + consumed foliage) ÷ length of entire crown (all foliage) × 100

Modifications to Table 2 based on Cambial Injury Rating

- Rating of 0 to 3 reduces the probability of mortality 5-15%
- Rating of 4 increases the probability of mortality by 40%

Red Turpentine Beetle

- When pitch tubes are absent, probability of mortality decreases a moderate amount (10-20%)
- When pitch tubes are present, probability of mortality increases a moderate amount (10-20%)

Table 3. Mortality of **Fire-Injured Lodgepole Pine** (based on Ryan and Reinhardt. 1988)

* **Percentage of live crown killed by fire** (the guidelines for lodgepole pine use volume of crown killed rather than length)

Probability the tree will die ⇨	**40%**	**60%**	**80%**
DBH (diameter of stem at breast height)			
≤ 10"	**--**	**5**	**40**
> 10 to 15"	**--**	**35**	**55**
> 15 to 20"	**25 ***	**40**	**60**

* volume of killed crown (brown + consumed foliage) ÷ vol. of entire crown (all foliage) × 100

No other variables are recommended; however, lodgepole pine has relatively thin bark and significant bark charring around the entire stem (cambial injury rating of 4) is likely to lead to mortality.

Table 4. Mortality of **Fire-Injured White Fir** (based on Hood *et al.* 2010)

* **Percentage of live crown killed by fire**

Probability the tree will die ⇨	**30%**	**50%**	**70%**
DBH (diameter of stem at breast height)			
10 to 35"	**65 ***	**75**	**80**
> 35"	**45**	**60**	**70**

* length of killed crown (brown + consumed foliage) ÷ length of entire crown (all foliage) × 100

Modifications to Table 4 based on Cambial Injury Rating:

- Rating of 0 causes no change in the probability of mortality
- Rating of 1 or 2 increases the probability of mortality by 10-20%
- Rating of 3 or 4 increases the probability of mortality by 15-30%

Hazard Tree Alert: white firs have a high probability of stem failure due to cambial kill and subsequent wood decay.

Table 5. Mortality of **Fire-Injured Red Fir** (based on Hood *et al.* 2007a)

*** Percentage of live crown killed by fire**

Probability the tree will die ⇨	**30%**	**50%**	**70%**
DBH (diameter of stem at breast height) **6 to 40"**	**45 ***	**70**	**80**

* length of killed crown (brown + consumed foliage) ÷ length of entire crown (all foliage) × 100

No other variables are recommended.

Hazard Tree Alert: red firs have a high probability of stem failure due to cambial kill and subsequent wood decay.

Table 6. Mortality of **Fire-Injured Douglas-fir** (based on Hood 2008)

*** Percentage of live crown killed by fire**

Probability the tree will die ⇨	**30%**	**50%**	**70%**
DBH (diameter of stem at breast height) **4 to 40"**	**25 ***	**65**	**75**

* length of killed crown (brown + consumed foliage) ÷ length of entire crown (all foliage) × 100

Modifications to Table 6 based on Cambial Injury Rating:

- Rating of 0 to 2 causes little change in the probability of mortality
- Rating of 3 or 4 increases the probability of mortality by 15-30%

Table 7. Mortality of **Fire-injured Incense Cedar** (based on Hood *et al.* 2010)

*** Percentage of live crown killed by fire**

Probability the tree will die ⇨	**30%**	**50%**	**70%**
DBH (diameter of stem at breast height) **10 to 60"**	**75 ***	**85**	**90**

* length of killed crown (brown + consumed foliage) ÷ length of entire crown (all foliage) × 100

No other variables are recommended.

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US Forest Service, Region 5, Forest Health Protection

May 2011 (Report # RO-11-01)

Replaces April 2009 Report # RO-09-01

Marking Guidelines for Fire-Injured Trees in California

Sheri L. Smith and Daniel R. Cluck

If you are using these marking guidelines for your post-fire restoration it is imperative that you contact your local Forest Health Protection (FHP) service area staff for review of your draft NEPA document (before public distribution), responses to comments and for assistance with marking guideline selection and project implementation.

Yellow pine (ponderosa and Jeffrey pine), white fir, sugar pine and incense cedar guidelines are based on: Hood, Sharon M.; Smith, Sheri L.; Cluck, Daniel R. 2010. *Predicting mortality for five California conifers following wildfire.* Forest Ecology and Management. 260: 750-762.

Red fir guidelines are based on: Hood, Sharon M.; Smith, Sheri L.; Cluck, Daniel R. 2007. *Delayed conifer tree mortality following fire in California* In: Powers, Robert F., tech. editor. Restoring fire-adapted ecosystems: proceedings of the 2005 national silviculture workshop. Gen. Tech. Rep. PSW-GTR-203, Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture: p. 261-283.

Douglas-fir guidelines are based on: Hood, Sharon M. 2008. *Delayed Tree Mortality following Fire in Western Conifers*. JFSP Final Report 05-2-1-105, US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Missoula, MT. 35 p.

Lodgepole pine guidelines are based on: Ryan, Kevin C.; Reinhardt, Elizabeth D. 1988. *Predicting post-fire mortality of seven western conifers.* Canadian Journal of Forest Research 18: 1291-1297.

The following guidelines use percent crown length killed (and percent crown length scorched for yellow pine) or percent crown volume killed (for Douglas-fir and lodgepole pine) only or in combination with dbh, cambium kill rating and/or the presence or absence of bark beetle activity. The yellow pine, white fir, incense cedar, sugar pine and red fir guidelines are based on five year post-fire data, the Douglas-fir guidelines are based on three year post-fire data and the lodgepole pine guidelines are based on three to eight year post-fire data.

The yellow pine guidelines are separated for percent of crown length scorched and percent crown length killed. The percent crown length scorched guideline is appropriate when evaluating trees in late season fires prior to subsequent bud break (heat killing of foliage may occur with only light injury to buds and twigs and the full extent of crown kill cannot be determined until bud break occurs). The percent crown length killed guideline is appropriate when evaluating trees post-bud break. The percent crown length killed guidelines for sugar pine, incense cedar and red and white fir, or the percent crown volume killed models for Douglas-fir and lodgepole pine are appropriate any time after fire injury (<u>all trees should be evaluated before the beginning of the second post-fire winter, preferably within the first post-fire year</u>).

Evaluation of Crown Injury

Visually estimate the percent crown length killed (PCLK) for **white fir, red fir, incense cedar and sugar pine** to the nearest 5 percent, by standing far enough back from the tree so that the entire crown is visible. Optimum viewing of the crown is against a blue sky away from the sun.

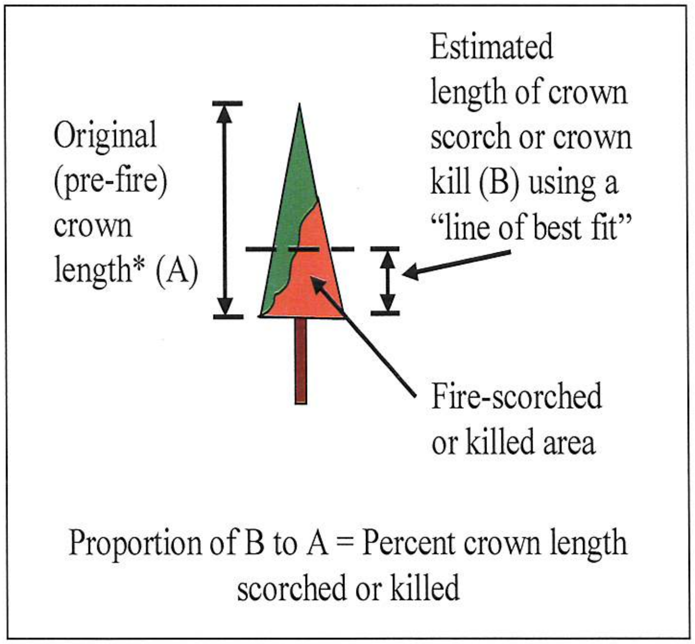


Figure 1. Estimating the percent crown length or scorched killed.

First, determine the original crown base height. Pre-fire crown base height can be estimated by looking at the fine branch structure and needles. Branches lacking fine twigs were likely dead before the fire. Trees often have asymmetrical crown bases so, if necessary, visually "move" some of the lower branches to the other side of the crown to even out the base.

Next, determine the crown kill height by establishing a "line of best fit" (Figure 1). Crown killed areas include any brown needles, as well as any areas that have blackened fine branches. If large gaps occur in the crown (> 4 feet in length), visually "move" lower branches up to fill in these areas. Be sure to evaluate the backside of the tree if its condition cannot be determined from the original vantage point.

Evaluate **yellow pine** *pre-bud break* (estimating percent crown length scorched or PCLS) using this same method and the *pre-bud break* guideline (Table 3). *Crown length is a linear measurement and does not account for crown shape.*

Visually estimate the percent crown length killed (PCLK) for **yellow pine** *post-bud break*, to the nearest 5 percent, by looking for completely dead branches (both scorched and/or blackened). Count an entire scorched branch as part of the live crown if green needles are extending from any of its lateral shoots (Figure 2).

Visually estimate the percent crown volume killed (PCVK) for **Douglas-fir and lodgepole pine**, to the nearest 5 percent, by comparing the volumetric proportion of crown kill (brown needles and blackened fine branches) to the volume occupied by the entire pre-fire crown. *Crown volume estimates consider crown shape.*


Figure 2. Bud survival on scorched branch.

Evaluation of Crown Injury

Figures 3 and 4 illustrate the different portions of fire-injured crowns for yellow pine and white fir and provide examples of the estimated crown length scorched (for pine) and crown length killed (for both pine and fir) as percentages of the original, pre-fire crown length.

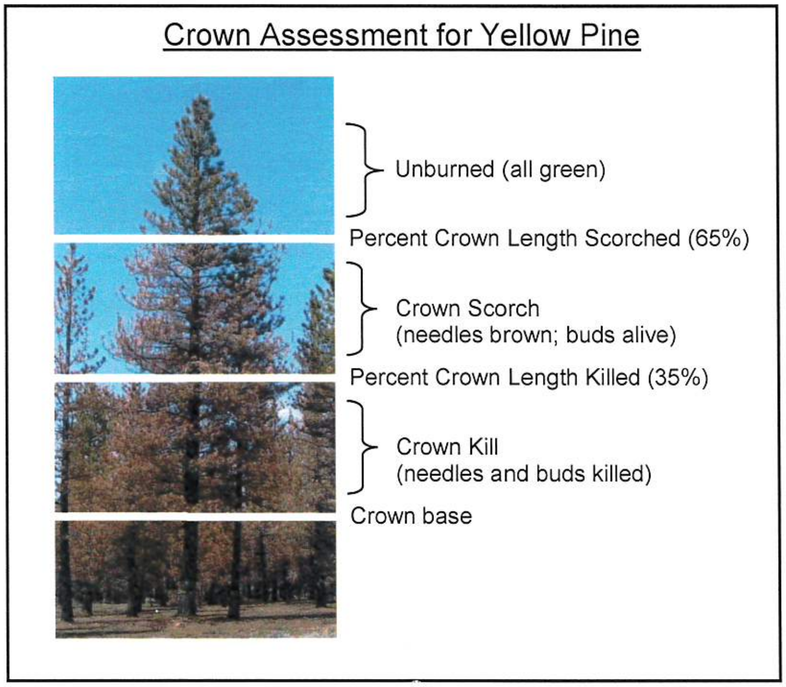


Figure 3. Crown assessment for yellow pine.

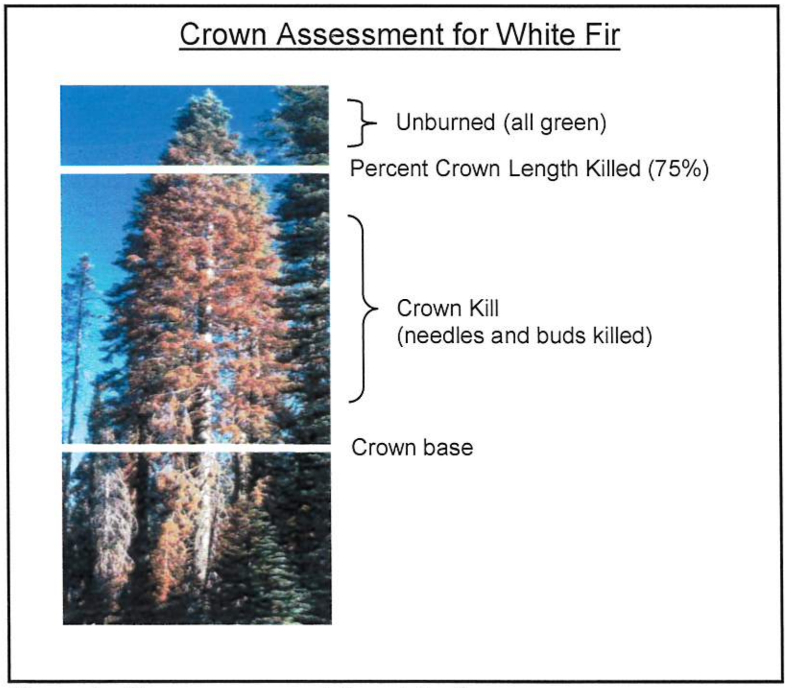
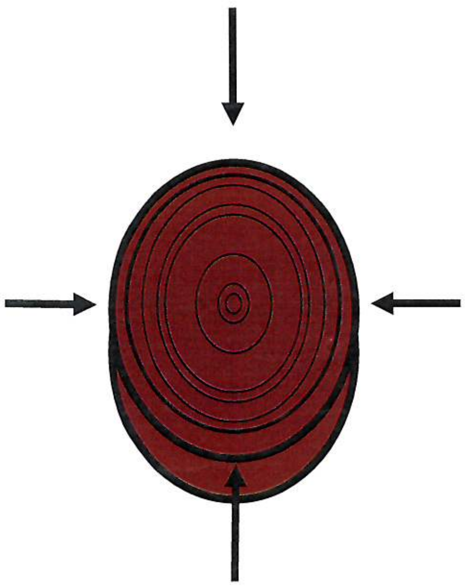


Figure 4. Crown assessment for white fir.

Evaluation of Cambium Injury



Sample cambium in as small an area as possible at 4 equally spaced locations around bole and within 3" of the ground line to minimize tree wounding (Figure 5)

Each sample is visually inspected in the field for color and condition of the tissue. Dead cambium is darker in color, often resin soaked and hard or gummy in texture. Live cambium is lighter in color, moist and rather pliable. Dead cells in the cambium zone also lose their plasticity which may allow the bark and wood to separate more easily (Ryan 1982). Add up the total number of dead samples (0 to 4) to determine the cambium kill rating (CKR). When both live and dead cambium is encountered in a sample choose the dominant condition of that sample (e.g. if more than half of the sample is dead then count it as dead).

Figure 6. Sampling cambium with a small hatchet.

Evaluation of Cambium Injury

Bark Charring as a substitute for direct cambium sampling

When salvage marking includes cambium sampling, additional time is required to assess each tree. Direct cambium sampling can be reduced by using unburned, light and deep bark char classes as a substitute (Hood et al 2008). **Moderately charred quadrants would still require direct sampling (except for lodgepole pine and Douglas-fir).** Divide the tree bole into four quadrants and assess the bark within 1 foot of ground line. Use the bark char class that best represents the majority of the area. Please refer to the following bark char descriptions (Ryan 1982) when substituting bark char classes for direct cambium sampling. Determine the CKR (0 to 4) as previously described.

Unburned or light charring – light charring has some blackened areas on the bark but unburned portions remain. These unburned portions are generally found in the bark fissures. *(Assume cambium is alive except for lodgepole pine; must directly sample lightly charred quadrants for lodgepole pine)*

Moderate charring – with moderate charring, all bark is blackened but the bark characteristics remain. *(Must directly sample to determine cambium status except for lodgepole pine and Douglas-fir; assume cambium is dead for moderately charred quadrants on lodgepole pine; assume cambium is alive for moderately charred quadrants on Douglas-fir)*

Deep charring – with deep charring, all the bark is blackened and bark characteristics are no longer discernable. *(Assume cambium is dead)*

Evaluation of Red Turpentine Beetle Activity

Figure 7. Red turpentine beetle pitch tubes.

Determine the simple presence or absence of red turpentine beetle pitch tubes (Figure 7) on yellow and sugar pine. The density or percent coverage of attacks around the bole is not a concern. The importance of this variable depends on the timing of the fire and the subsequent level of red turpentine beetle activity and is only used when significant activity is detected. FHP personnel can assist with this determination. Even though the presence of red turpentine beetle pitch tubes is used as criterion in some of the pine guidelines, it should not be used exclusively to mark trees for removal (see top of page 8).

Determining what variables to use when marking trees

Managers need to determine how much time is available for assessing each tree. The most accurate marking guidelines (requiring the most time) assess crown injury, cambium injury and red turpentine beetle (RTB) activity (for yellow and sugar pine). At a minimum, a crown injury assessment is required for all species. Assessing cambium injury and/or RTB activity (for yellow and sugar pine) requires additional time per tree but does provide a slight increase in accuracy for white fir, sugar pine and yellow pine. In general, if managers choose to only assess crown injury and the fire resulted in cambium kill ratings >2 on most trees, mortality will be under predicted. The opposite is true if the fire resulted in cambium kill ratings of ≤ 2 on most trees, as mortality will then be over predicted (this varies by tree species). Mortality could also be under or over predicted if RTB activity is not assessed (depends of level of post-fire RTB activity). Knowledge of fire behavior, pre-fire fuel conditions and post-fire RTB activity will help to determine the value of assessing for these variables.

Selecting the predicted probability of mortality (Pm) level that will meet land management objectives

The probability of mortality (Pm) levels incorporated into the guidelines are thresholds where all trees meeting or exceeding a selected Pm level are marked for removal. Providing a range of Pm levels afford land managers more options to meet post-fire management objectives. The number of trees removed from a project area will generally vary with different Pm levels; fewer trees will be marked at higher Pm levels (a more conservative mark) and more trees will be marked at lower Pm levels (a less conservative mark) (Figure 8). The exact amount of difference in the mark between Pm levels depends on the population of fire-injured trees within the project area. For example, if the project consists primarily of high severity burn areas the number of trees marked for removal will not significantly change with different Pm levels.

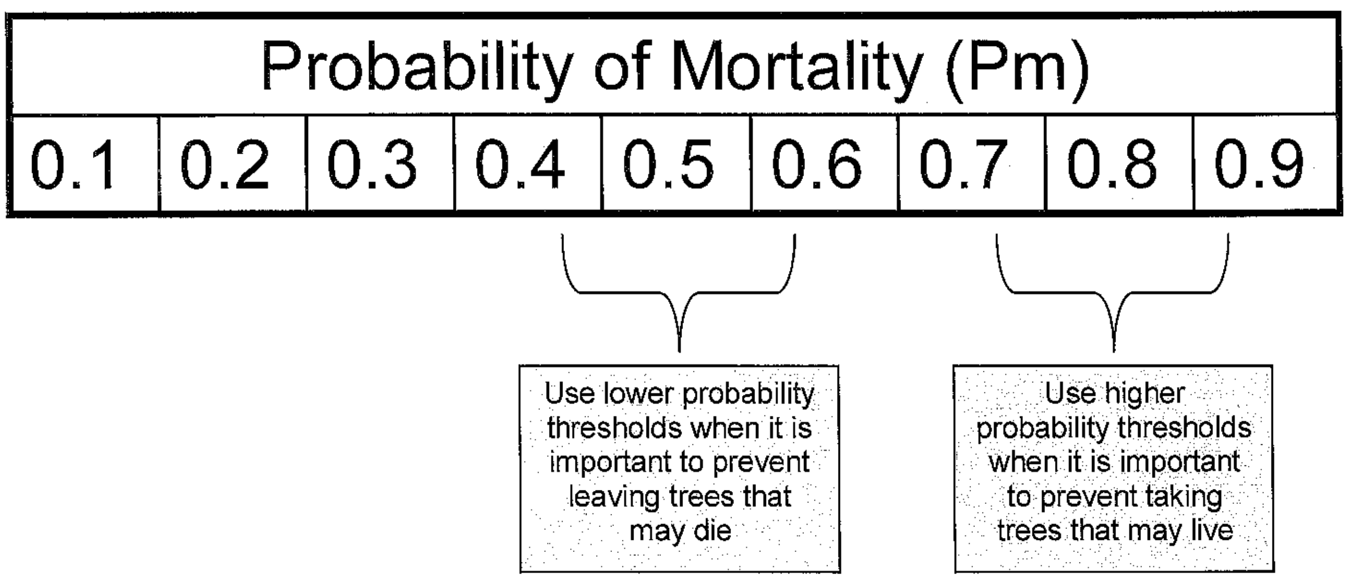


Figure 8. General recommendations based on management objectives for various Pm levels.

The selection of the Pm level should take into consideration the following factors:

- The population of fire-injured trees within the project area [can be based on vegetation burn severity maps showing low, moderate and high severity (Figure 9)]
- Management objectives and desired future conditions
- Number of harvest entries allowed
- Post-salvage fuels objectives
- Snag requirements
- Method of harvest: tractor, helicopter, cable, etc
- Economics and logistics (availability of marking crews and operators, timber values, length of contracts, etc.)
- Reforestation plans: planting and/or natural regeneration
- NEPA process
- Hazard trees
- Environmental conditions (drought, stand density, and beetle activity)

After identifying project-specific objectives, conditions and requirements, land managers should be able to determine which Pm level, or levels (more than one may be selected), will best meet their needs. Consultation with Forest Health Protection staff and other land managers that have implemented projects using these guidelines can greatly assist in making a Pm selection. It is also recommended that land managers document the rationale used to make Pm level selections for future reference.

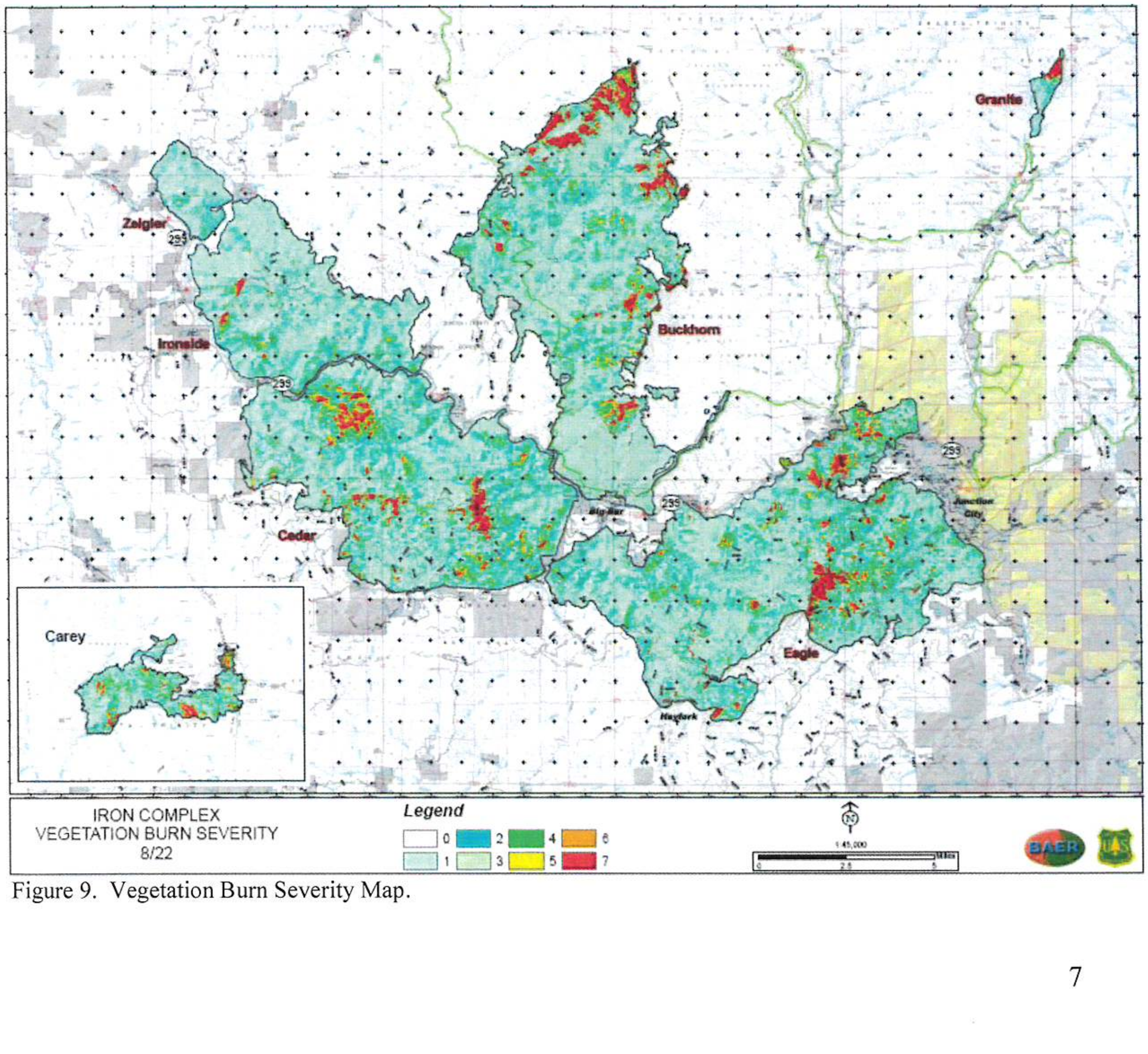


Figure 9. Vegetation Burn Severity Map.

MARKING GUIDELINES FOR FIRE-INJURED TREES

Evidence of significant bark and/or wood boring beetle activity

(Any tree meeting this criteria is predicted to die and no further assessment is required)

Trees should be marked for removal if any combination of the following factors are present over at least 1/3 of the bole circumference: 1) pitch tubes with pink or reddish boring dust associated with them (not clear pitch streamers); 2) pouch fungus conks and/or current woodpecker activity (holes into the sapwood and/or bark flaking, specifically excludes injury caused by sapsucker feeding); 3) boring dust or frass (in bark crevices, webbing along the bole, or that accumulates at the base of the trees). This specifically excludes basal attacks by the red turpentine beetle (large pitch tubes associated with coarse boring dust generally restricted to the lower 2 to 3 feet of the bole or woodpecker activity restricted to this area)* and when the above indicators are only associated with wounds, old fire scars, etc. (Cluck 2008)

*The presence or absence of red turpentine beetle pitch tubes are incorporated into the yellow pine marking guidelines in Tables 2a and 2b.

YELLOW PINE

Table 1 or Tables 2a and 2b are to be used when evaluating trees ***post-bud break.***
Table 3 is used when evaluating trees ***pre-bud break.***

Table 1. YELLOW PINE: percent crown length killed (PCLK) and DBH *(use post-bud break)**

- Use Table 1 when only assessing crown injury.

Probability of mortality (Pm)	.10	.20	.30	.40	.50	.60	.70	.80	.90
DBH	Percent crown length killed (PCLK)								
10 - <30"	25	35	40	45	50	55	60	65	70
30 - 40"	--	5	10	15	25	30	40	45	60
>40 - 50"	--	--	--	5	10	15	25	30	45

Table 2a. YELLOW PINE: PCLK, DBH and red turpentine beetle pitch tubes PRESENT*

- Use Tables 2a and 2b when assessing crown injury and red turpentine beetle presence/absence
  Note: Use of this guideline is appropriate when significant red turpentine beetle activity is detected. FHP personnel can assist with this determination.

Probability of mortality (Pm)	.10	.20	.30	.40	.50	.60	.70	.80	.90
DBH	Percent crown length killed (PCLK)								
10 - <30"	10	30	35	40	45	50	55	60	65
30 - 40"	--	--	--	--	--	5	10	15	25
>40 - 50"	--	--	--	--	--	--	--	5	10

YELLOW PINE (continued)

Table 2b. YELLOW PINE: PCLK, DBH and red turpentine beetle pitch tubes ABSENT*

Probability of mortality (Pm)	.10	.20	.30	.40	.50	.60	.70	.80	.90
DBH	**Percent crown length killed (PCLK)**								
10 - <30"	30	35	50	55	60	65	70	75	80
30 - 40"	5	10	20	25	30	40	45	55	65
>40 - 50"	--	--	--	5	10	15	25	35	45

* When the cambium kill rating (CKR) is determined for **yellow pine,** *post-bud break,* use the following percent crown length killed adjustments for Tables 1, 2a and 2b: For yellow pine **10 - <30" dbh,** *add* 5 percentage points when CKR = 0 or 1, *no change* when CKR = 2, and *subtract* 10 percentage points when CKR = 3 or 4. For yellow pine **>30" dbh,** *add* 5 percentage points when CKR = 0 or 1, *no change* when CKR = 2, and *subtract* 5 percentage points when CKR = 3 or 4.

Table 3: YELLOW PINE: percent crown length scorched (PCLS) and DBH *(use pre-bud break)**

- *Note: The red turpentine beetle guideline is not used in the pre-bud break model*

Probability of mortality (Pm)	.10	.20	.30	.40	.50	.60	.70	.80	.90
DBH	**Percent crown length scorched (PCLS)**								
10 - <30"	50	50	70	75	80	85	90	95	100
30 - 40"	10	25	35	40	45	55	60	70	80
>40 - 50"	--	10	15	20	30	35	40	50	65

* When the cambium kill rating (CKR) is determined for **yellow pine,** *pre-bud break,* use the following percent crown length scorched adjustments for Table 3: For yellow pine **10 - <30" dbh,** *add* 15 percentage points when CKR = 0, *add* 10 percentage points when CKR = 1, *no change* when CKR = 2, *subtract* 10 percentage points when CKR = 3 and *subtract* 15 percentage points when CKR = 4. For yellow pine **>30" dbh,** *add* 5 percentage points when CKR = 0, *no change* when CKR = 1, *subtract* 5 percentage points when CKR = 2, and *subtract* 10 percentage points when CKR = 3 or 4.

INCENSE CEDAR

Table 4: INCENSE CEDAR - percent crown length killed (PCLK)*

Probability of mortality (Pm)	.10	.20	.30	.40	.50	.60	.70	.80	.90
DBH	**Percent crown length killed (PCLK)**								
10 – 60"	65	70	75	80	85	85	90	90	95

* Cambium sampling is not recommended for incense cedar.

SUGAR PINE

Table 5: SUGAR PINE - percent crown length killed (PCLK)*

- Use Table 1 when only assessing crown injury.

Probability of mortality (Pm)	.10	.20	.30	.40	.50	.60	.70	.80	.90
DBH	**Percent crown length killed (PCLK)**								
10 – 60"	--	30	40	50	50	55	60	65	70

Table 6a: SUGAR PINE - PCLK and red turpentine beetle pitch tubes PRESENT*

- Use Tables 6a and 6b when assessing crown injury and red turpentine beetle presence/absence *Note: Use of this guideline is appropriate when significant red turpentine beetle activity is noted. FHP personnel can assist with this determination.*

Probability of mortality (Pm)	.10	.20	.30	.40	.50	.60	.70	.80	.90
DBH	**Percent crown length killed (PCLK)**								
10 – 60"	--	--	--	30	40	45	55	60	65

Table 6b: SUGAR PINE - PCLK and red turpentine beetle pitch tubes ABSENT*

Probability of mortality (Pm)	.10	.20	.30	.40	.50	.60	.70	.80	.90
DBH	**Percent crown length killed (PCLK)**								
10 – 60"	30	45	55	60	60	65	70	75	80

* When the cambium kill rating (CKR) is determined for **sugar pine**, use the following percent crown kill adjustments for Tables 5, 6a and 6b: *Add* 5 percentage points when CKR = 0 - 3 and *subtract* 20 percentage points when CKR = 4.

WHITE FIR

Table 7. WHITE FIR: percent crown length killed (PCLK) and DBH * °

Probability of mortality (Pm)	.10	.20	.30	.40	.50	.60	.70	.80	.90
DBH	**Percent crown length killed (PCLK)**								
10 - 35"	50	60	65	70	75	80	80	85	90
>35 - 60"	--	35	45	50	60	65	70	75	80

* When the cambium kill rating (CKR) is determined for **white fir,** use the following percent crown kill adjustments for Table 7: *Subtract* 5 percentage points when CKR = 1 or 2, *subtract* 10 percentage points when CKR = 3 or 4 and *no change* when CKR = 0.

° FHP monitoring of fire-injured **white fir** revealed high levels of decay developing where significant cambium kill occurred at the root collar and on the bole. A portion of these decayed trees failed during the five-year period while still retaining green foliage. Land managers should be aware that even though true firs with high levels of cambium kill have a high probability of survival they may become hazards to people or property (Cluck 2005).

RED FIR

Table 8. RED FIR: percent crown length killed (PCLK) °

Probability of mortality (Pm)	.10	.20	.30	.40	.50	.60	.70	.80	.90
DBH	**Percent crown length killed (PCLK)**								
6 – 40"	--	40	45	65	70	75	80	85	95

° FHP monitoring of fire-injured **red fir** revealed high levels of decay developing where significant cambium kill occurred at the root collar and on the bole. A portion of these decayed trees failed during the five-year period while still retaining green foliage. Land managers should be aware that even though true firs with high levels of cambium kill have a high probability of survival they may become hazards to people or property (Cluck 2005).

DOUGLAS-FIR (Hood 2008)

Table 9. DOUGLAS-FIR: percent crown volume killed (PCVK), and DBH *

- This guideline uses ***percent crown volume killed*** (not percent crown length killed). Visually estimate the volumetric proportion of crown killed compared to the space occupied by the pre-fire crown volume to the nearest five percent (Ryan 1982).

Probability of mortality (Pm)	.10	.20	.30	.40	.50	.60	.70	.80	.90
DBH	**Percent crown length killed (PCLK)**								
4 – 40"	--	10	25	55	65	70	75	80	90

* When the cambium kill rating (CKR) is determined for **Douglas-fir**, use the following percent crown kill adjustments for Table 9: *Add* 5 percentage points when CKR = 0, *no change* when CKR = 1, *subtract* 5 percentage points when CKR = 2, *subtract* 10 percentage points when CKR = 3, *subtract* 20 percentage points when CKR = 4.

LODGEPOLE PINE (Ryan and Reinhardt 1988)

Table 10. LODGEPOLE PINE: percent crown volume killed (PCVK) and DBH

- This guideline uses ***percent crown volume killed*** (not percent crown length killed). Visually estimate the volumetric proportion of crown killed compared to the space occupied by the pre-fire crown volume to the nearest five percent (Ryan 1982).

Probability of mortality (Pm)	.10	.20	.30	.40	.50	.60	.70	.80	.90
DBH	**Percent crown volume killed (PCVK)**								
≤10"	-	-	-	-	-	5	30	40	55
>10 - 15"	-	-	-	-	20	35	45	55	70
>15 – 20"	-	-	-	25	35	40	50	60	70
All lodgepole pine, regardless of diameter, are predicted to die if all bole quadrants have moderate or deep char as defined by Ryan (1982) (Hood 2006).									

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Appendix A: Project specific guideline example

Marking Guidelines for Fire-injured Trees: Scorch Fire Salvage Project

Guideline Objectives: *These guidelines will provide a means to identify and remove trees that were killed or severely injured as a result of fire and/or insect attack within the Scorch Fire, California Ranger District.*

These guidelines are based on the fire injured tree marking guidelines developed by Region 5 Forest Health Protection (Report #RO-11-01, Smith and Cluck, May 2011). The guideline criteria (#3) for delayed conifer tree mortality are based on the post-bud break model (% crown length killed) for yellow pine, and the white fir and red fir models (% crown length killed). A probability of mortality of 0.7 (Pm=0.7) was selected for this project to meet the management objectives of: 1) removing trees that were killed or that have a high probability of mortality to recover their economic value; and 2) retaining those trees that have a moderate to high probability of survival to provide forest cover as a seed source for natural regeneration and wildlife habitat. **All trees >40" dbh, regardless of condition, will be retained to provide for wildlife except when they pose a hazard to people or property.**

> **Note:** The Smith and Cluck 2011 guidelines also discuss the evaluation of cambium injury (for yellow pine, sugar pine and white fir) for adjusting crown kill marking criteria. The Scorch Fire Salvage Project marking guidelines **DO NOT** include cambium sampling for this purpose due to the additional time required to assess individual trees and the minimal loss of accuracy incurred by dropping this variable.

Mark for removal any tree that meets the following criteria:

1. Any tree with no green needles (does not include those designated for snag retention).

2. For all species, trees should be marked for removal if any combination of boring dust or frass (in bark crevices, webbing along the bole, or that accumulates at the base of the trees), pitch tubes with pink or reddish boring dust associated with them, pouch fungus conks and/or current woodpecker activity (holes into the sapwood and/or bark flaking, specifically excludes injury caused by sapsucker feeding) is present over at least 1/3 of the bole circumference. This specifically excludes basal attacks by the red turpentine beetle on pines (large pitch tubes associated with coarse boring dust generally restricted to the lower 2 to 3 feet of the bole or woodpecker activity restricted to this area) and when the above indicators are only associated with wounds, old fire scars, etc. The presence or absence of red turpentine beetle pitch tubes will be accounted for in criteria #3.

3. Any tree that meets or exceeds the following fire-injured conifer mortality guidelines (Table 1) at the Pm = 0.7 level. This assessment will be made by visually estimating the percent of the original pre-fire crown length that was killed (yellow and sugar pine, white and red fir), the presence or absence of red turpentine beetle pitch tubes (yellow and sugar pine) and tree diameter (yellow pine and white fir).

Table 1: Specific criteria for marking fire-injured trees at the Pm = 0.7 level.

Yellow Pine – Red turpentine beetle absent	
DBH	**Minimum % Crown Length Killed**
10 - <30″	70
30 - 40″	45
Yellow Pine – Red turpentine beetle present	
DBH	**Minimum % Crown Length Killed**
10 - <30″	55
30 - 40″	10
Sugar Pine – Red turpentine beetle absent	
DBH	**Minimum % Crown Length Killed**
10-40″	70
Sugar Pine – Red turpentine beetle present	
DBH	**Minimum % Crown Length Killed**
10-40″	55
White fir	
DBH	**Minimum % Crown Length Killed**
10 - 35″	80
>35 - 40″	70
Red fir	
DBH	**Minimum % Crown Length Killed**
10-40″	80

References for Scorch Fire Salvage Marking Guidelines

Cluck, D.R. 2008. *Salvage Marking Guidelines for the Lassen, Plumas, Modoc and Tahoe National Forests.* US Forest Service, Forest Health Protection, Northeastern California Shared Service Area, Susanville, CA. 4 p.

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