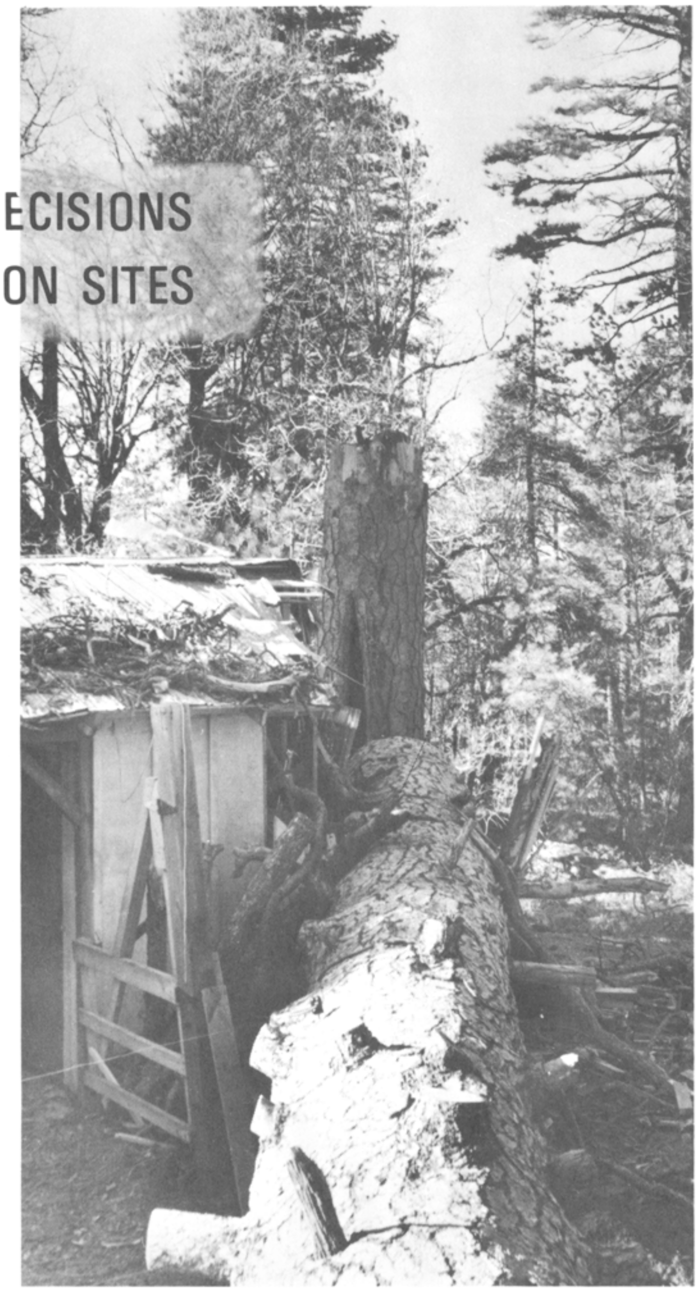
PACIFIC SOUTHWEST
Forest and Range
Experiment Station

FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE
P.O. BOX 245, BERKELEY, CALIFORNIA 94701

ACCIDENT HAZARD EVALUATION AND CONTROL DECISIONS ON FORESTED RECREATION SITES

Lee A. Paine



USDA FOREST SERVICE RESEARCH PAPER PSW- 68 /1971

CONTENTS

The Author

LEE A. PAINE is studying problems in the biology and control of forest tree diseases, particularly in recreation site pathology. A plant pathologist, he has been on the Berkeley Station staff since 1957, when he joined the Forest Service. He holds bachelor's (1943) and master's (1947) degrees in forestry from the University of Idaho and a doctor of science degree (1951) from the Swiss Federal Institute of Technology.

GLOSSARY

Cleanup: post-failure removal of debris.

Control: reduction of hazard to acceptable level by removal or treatment of tree, or by limiting exposure of targets, before a tree has failed.

Damage Potential: capacity of a tree failure to cause damage as compared to that expected from uprooting of a 70-inch (d.b.h.) softwood tree.

Failure Class: the type of failure (limb, upper bole, lower bole, butt or uprooting) which is anticipated when rating hazard.

Fixed Property: buildings, facilities, or equipment exposed to hazard throughout the year.

Hazard: expected accident loss resulting from mechanical failure of a tree during current inspection cycle if no control is undertaken.

Hazard Control Level: a specific value of hazard rating selected for use in making control decisions.

Hazard Rating: estimate of hazard.

Impact: striking of a target or area by a failing tree or tree part.

In-Season: usual period of site use by recreationists.

Occupancy: presence of target on recreation unit.

Safety Standard: statement defining the allowable rate of accident loss or tree failure for an administrative region.

Site: defined area, usually with a number of units, providing recreation opportunities, and services or management facilities or both.

Target: person or property exposed to hazard.

Target Value: dollar value of property exposed to hazard.

Unit: area intended for recreational use by one family at a time.

↓ *Activities of man often cause defect. Subsequent erosion increases the probability of failure.*

Statistically predictable environmental factors, such as flooding or streambank erosion, affect the probability of failure. ↑

↓ *People and property contribute to hazard–without potential loss there is no hazard.*

Careful evaluation is required when a tree on a heavily used site shows defect with a high damage potential. ↑

←
Recreationists fail to acknowledge hazardous situations even when a tree is obviously defective. Hollow trunks are sometimes used as food storage cabinets.

Hazard control on public recreation sites has never been studied with the aims of determining the underlying factors involved in hazard and of providing a practical approach to a predictable and uniform level of control. As a consequence, levels of control vary drastically from one site to the next, and the effectiveness of control cannot be predicted even over large administrative areas.

This paper defines, for the first time, the factors involved in accident hazard associated with trees and their interrelationships, and provides a practical method for hazard evaluation. An understanding of the factors involved in hazard evaluation and adoption of the recommended procedures will provide more uniform levels of public safety with greater economy for the chosen level of control. The hazard evaluation procedure was made possible through extensive research and analysis of tree failure records provided by many cooperating agencies.

In this paper, hazard is defined as the expected loss from mechanical failure of a tree during the current inspection cycle–unless the probability of an accident is reduced. Hazard may thus be expressed in terms of dollars.

UNDERSTANDING HAZARD AND HAZARD CONTROL

The Goal and the Problem

The goal of hazard evaluation and control is to provide an acceptable level of public safety at minimum cost and with the least damage to the environment. Observation of many recreation sites has shown that hazard from defective or faulty trees is often higher than recognized, and that levels of hazard control vary greatly within and between sites. Some sites are over controlled at excessive cost and loss to the site. Few managers can be confident that they are achieving the goal as stated above.

This situation results partly from the impossibility of satisfying unrealistic directives–at any cost; partly from lack of a standard to measure performance of current control programs; and partly arises from limited tools and inadequate field procedures for rating hazard. Our objective is to improve field procedures through better understanding of the factors involved in hazard. But better tools and realistic goals and standards are also necessary to realize the potential of improved field methods.

This paper does not recommend any specific degree of control. This is an administrative decision which should rest on consideration of socially acceptable risks in relation to costs and benefits.[1] Some administrations may well decide that hazard control is not justified, or is justified only for certain use categories. But, if practiced, hazard control should meet the goals of safety, cost, and protection of the environment.

The hazard rating procedure (see the *Field Guide*) is intended to provide a consistent, realistic estimate of hazard. The many agencies which have contributed to its development will find that it can be readily adapted to their specific requirements. However, with any method of assessing hazard, the examiner should recognize that hazard is inevitably and directly dependent on the four factors included in the procedure. These factors can be ignored only at the cost of logic and predictable results.

Can All Hazard be Controlled?

Trees cannot be separated into hazardous and nonhazardous groups. Nearly all trees on a recreation site have a recognizable probability of failure and involvement in an accident. And safety costs trees as well as money. Consequently, we could never create absolutely safe conditions without removing most of the trees. If we could control all probable hazard, no one would *want* absolute safety at such a cost. Many trees with recognizable hazard must be retained or the site will lose its value and usefulness. Specimen trees, especially, will be retained even with increased risk. Safety will always be a compromise between costs of control, esthetic values, and accident losses–just as it is in automobile and in highway design.

It is high time we admit that we cannot achieve complete safety–and still provide a desirable product–any more than industry can. It is time to define our goals and standards, so that we have a basis for

[1] Administrative goals and safety standards for management of hazard control programs for recreation sites will be described in a forthcoming report.

measuring the performance of our safety programs and for evaluating efforts at improvement.

How Much Safety?

There is absolutely no way of deciding how much safety is warranted, or what accident losses are acceptable, except by definition–an arbitrary level set by administrative policy. After the definition has been stated, a safety standard and a control decision rule can be set. Only after a realistic safety standard has been designated, can the performance of a hazard control program be gauged.

In the absence of administrative standards, an arbitrary decision rule can usefully be established at any office–and it will provide an undefined but specific degree of safety at an appropriate cost. In this case, since no safety standard is specified, no grounds exist for deciding if the achieved degree of safety is adequate, or if control costs are excessive.

In the more desirable situation, a decision rule is designed to satisfy a safety standard. Accident losses are held to an amount *defined* as being compatible with control costs and esthetic costs. Such a rule must derive from more extensive data than are available over a short period on a single district or an entire forest.

Control Decision Rules

Decision rules are vital in any logical approach to hazard control. The examiner must decide in each situation if control is required. An action guide or decision rule is needed for deciding whether control is necessary and for attaining a consistent level of control. There are several possible rules for individual control decisions; one relies on maximum allowable hazard. The maximum hazard allowable without control work is defined as the hazard control level. The decision rule may be stated as follows: *When the expected loss from a tree is higher than the hazard control level, the hazard must be reduced.* By working to this level, the examiner aims at achieving a specific minimum level of safety. And the purpose of hazard rating is to achieve the selected level at the lowest cost to the site and budget. After each hazard has been rated, the examiner can decide immediately with the rule given above whether control is warranted.

Should his budget not permit control down to the level set, he can revise the level upward or adopt a different rule. Rules which consider varying control budgets or the esthetic and cultural values of individual trees are possible. All of the rules can be applied equally well to the basic hazard rating.

Setting Hazard Control Levels

The hazard control level is a specific value of expected loss selected for use in a decision rule. It has nothing to do with hazard rating. If the decision rule is followed, hazard associated with any higher expected loss will be controlled. A single control level should be set for large administrative areas to promote uniformity in conditions of public safety. This single level is much easier to justify than levels which vary from district to district or forest to forest.

Until a uniform administratively defined level has been established, the examiner can set a local hazard control level by first rating a selection of trees. After deciding which trees would be controlled under current practice, the examiner can set the hazard control level equal to the rating of the lowest-rated tree judged to need control. Subsequent control decisions will then depend on whether or not each hazard rating exceeds this hazard control level.

Minor branch hazard should not be considered in setting a local hazard control level because the damage potential (and expected loss) is usually low *(tables 1,2–see pages 7,8)* In general, control of branch hazard will be minimized when working to a hazard control level.

Good Hazard Control Practice

Good control practice starts with evaluation and preparation of sites for future use. Hazard evaluation should always be an important consideration in planning a new site. Selection of inappropriate sites and excessive costs of control can be minimized by starting hazard evaluation early.

Removal of defect is not always the best means of hazard reduction. The same degree of control can be effected by limiting access to a site or by mechanically reinforcing the tree. With specimen trees, especially, the desired hazard reduction can often be obtained by relocation of trails, fences, and facilities to reduce exposure of targets without destroying the value of the trees. Especially valuable trees warrant the expense of horticultural procedures such as bracing for reduction of hazard.

Changes in other site factors usually forebode changes in hazard. Alterations resulting from control activities, use patterns, weather cycles, and invasion by disease or insects may all affect hazard.

Consistent and economical hazard reduction depends not only on *selection of an appropriate control decision rule,* but also on *recognition* of defects and faults in trees; and *rating* of hazard.

Recognition and evaluation of defect require skill and experience. These abilities can be improved through training and application of currently available information. But, whatever his training, an examiner must appreciate the interacting factors which determine hazard if he is to make reliable decisions.

In this discussion, we are concerned with defining these factors and clarifying their interaction.

FACTORS IN HAZARD

Accident hazard is inherently concerned with: (a) the probability of tree failure; (b) the probability of the tree striking a target, or impact, if failure occurs; (c) the damage potential of the possible failure; and (d) the target value. If any one of these factors is minor, hazard is minimal. Hazard varies directly with each factor. Thus, if we assume they are equally important, hazard may be evaluated as the product of the four factors.

Rating hazard by this means makes it possible to rank hazardous situations. A specified hazard control level and numerical ranking of hazard provide a guide to control decisions and a basis for budgetary planning. If the budget is limiting, hazard rating makes efficient use of funds by giving priority to the worst hazards. With a specified control level, hazard rating promotes uniform levels of control throughout an administrative area.

Probability of Failure

Every tree will ultimately fail unless removed. The task in rating hazard is to estimate the probability of failure during a specific period. However, we are primarily concerned with trees which, because of their visible condition, location, or some detectable defect, are unusually susceptible to failure.[2]

We are concerned only with probability of failure before the next inspection. Most failures are triggered by some critical weather situation. For a specific tree during one inspection cycle, the probability of failure is the probability of any influence (e.g., wind or snow) sufficient to cause failure. If such conditions occur about twice in every 10 years, the probability for any given year is 2/10 or 20 percent.

In estimating the probability of failure, each tree inspected should be examined both for weakening defects and for faults resulting from poor growth or location (abnormally heavy limbs, weak crotches, unusual exposure to wind, or superficial rooting). When a defect or fault is detected, the type and intensity of those conditions most likely to cause failure are estimated (e.g., 40-m.p.h. winds). The probability of failure (i.e., the probability of such weather conditions during the current inspection cycle) is then estimated.

For potential failures which might affect in-season visitors, the estimate should be based on the occurrence of critical weather conditions in-season, only. If an estimate is required for fixed property, it should be based on year-round weather conditions. Since a hazard rating is usually higher for human occupancy, an estimate will not be necessary for fixed property exposed to the same potential failure unless the property is especially valuable.

When a defect or fault is so severe that the tree may collapse under the least stress, the probability of failure will be 100 percent.

Estimating the probability of weather conditions that will cause failure is difficult. But it is exactly *the same procedure that we normally follow* in selection of trees for hazard control. We are simply defining the process and the variables.

Without probability-of-failure as a guide to control decisions, the examiner is committed to operating on the basis of some arbitrary or capricious definition of what constitutes a "dangerous" tree. And unless estimates can be expressed numerically, he is reduced to intuitive evaluations. The problem is not in expressing probabilities numerically, but rather in improving our score by attention to the basic causes of hazard.

Probability of Target Impact

The probability of a target being struck if a particular tree fails is really a joint probability that (a) the falling tree will strike a specific area, and that (b) the area will be occupied. The probability of failure times the probability of impact is approximately the probability of an accident. Accident *loss* also depends on two components: (a) the ability of the class of failure to inflict damage, and (b) the value of the target. Thus hazard may be evaluated as the probability of an accident times the probable loss if an accident occurs, or *the expected loss this year if the hazard is not reduced.*

[2] This statement reflects the viewpoint that evaluation of tree hazard should cover all detectable or foreseeable circumstances. As methods of detection improve, our evaluations should become more critical.

Human Occupancy

For human occupancy, I recommend that the probability of impact be taken as the probability of occupancy. When we rate a tree with a significant probability of striking an area subject to human occupancy, we thus tacitly assume that it is sure to strike the occupied unit if it fails.

For such a tree, the probability of target impact for recreationists or their effects is taken as the probability of the unit being occupied during the season of use. This probability can be expressed as the ratio of occupancy days to total season days (percentage of full season occupancy). Season days are based on the average or anticipated season of use. Unit occupancy days may be estimated for the unit or based on the average for the entire facility. Unit occupancy should represent the number of days a site is occupied by one or more persons without giving additional weight to multiple occupants.

With a season of 100 days and occupancy of a unit by one or more visitors for 75 days, the probability of target impact if a failure occurs may be estimated as unit occupancy days/season days = 75/100 = 75 percent. This estimate provides bias in favor of the recreationist since it assumes target impact if the unit is occupied at the time of failure.

For common-use facilities, such as lavatories, impact probability for human occupancy can be expressed similarly: total days utilized/season days. On this basis, the probability of impact will be equal to or greater than that for any one of the camp units served by the facility. For between-unit or peripheral areas occupancy may be estimated with regard to occupancy for adjacent camp units.

Fixed Property

For permanently situated property, the probability of occupancy is always 100 percent. Probability of target impact is simply the probability that the occupied area will be struck if the tree fails. This probability is estimated by the examiner on the basis of direction of lean, direction of prevailing winds, or other pertinent factors. The examiner may judge that, if the tree failed, it would land within an 80° arc of which the fixed property occupies 20°. The probability of impact could then be estimated as 20°/ 80° = 25 percent.

Damage Potential

Evaluation of the hazard or expected loss associated with an uncontrolled defect requires an estimate of the relative danger associated with each class of defect. A small limb causes less damage than a bole, and the average damage potential of a softwood bole differs from that of a hardwood bole. To provide the examiner with a guide to damage potential, two tables derived from field data supplied by cooperating agencies are included in this report. They list average loss for class of failure, d.b.h., and tree group as compared with the maximum loss expected from uprooting of a 70-inch d.b.h. softwood[3] (*tables 1,2).*

Table I provides a damage potential guide for exposure of recreationists and their property. The figures are based on property losses of recreationists plus evaluation of fatalities and injuries requiring medical treatment. The 1968 losses used for evaluating personal injuries and fatalities were supplied by the National Safety Council.

Table 2 provides guide numbers for damage to fixed property. These damage potential figures multiplied by the dollar value of the target reflect the expected property loss in an accident. The figures are based only on failures causing property damage. Losses are also related to tree species, but data now available do not permit further breakdown.

The two tables cover only the d.b.h. range of trees involved in reported accidents. As with any such experience table, the damage potential values are guides which will provide valid average estimates when correctly applied. They will not necessarily predict a particular situation accurately.

In deriving the damage potential guide tables, losses involved in accidents were first analyzed for tree species and class of failure. Groups which showed similarity were then combined as indicated in *tables 1 and 2.* Curves relating d.b.h. to loss were fitted to the data for each group and tested for best fit. To provide a multiplying factor expressing the potential for damage of a d.b.h. and failure class, each curve value for a given d.b.h. was divided by the expected loss in an accident involving the uprooting of a 70-inch d.b.h. softwood. The published guide numbers are thus derived from the fitted curves, but represent the potential for damage of any one failure class and d.b.h. as compared with that of an uprooting 70-inch d.b.h. softwood.

Target Value

The target value may be defined as the maximum possible loss if the target is involved in an accident. However, a constant target value of $4,000 is recommended with any recreationist occupancy. This figure is based on personal injury and property losses

[3] Based on maximum size range included in *tables 1 and 2.*

resulting from tree failure accidents involving only recreationists.[4]

With fixed property, its actual value may usually be estimated in dollars for a target value. Occasionally, the target is so large that an accident involving a 70-inch tree could not result in total loss. In this case, the assigned target value is the maximum loss that would result from an uprooted 70-inch d.b.h. softwood falling on the exposed target. For example, a $30,000 building might have an estimated maximum loss of $7,000 in such an accident. It would thus be assigned a target value of $7,000.

HAZARD RATING

Hazard is a function of the probability of tree failure, the probability of target impact, the damage potential, and the target value. We may define the *hazard rating* as the product of our estimates of these factors. For human occupancy, the rating provides an estimate of expected loss biased in favor of the recreationist. For fixed property, the hazard rating provides a direct estimate of the expected dollar loss during the current inspection cycle if the hazard is not reduced.

The rating provides an evaluation of hazard in any one situation as compared with other situations rated by the same method. Priority can be given to the highest rated hazard, with hazard reduction applied to all trees rated above the administrative hazard control level.

Our prime concern is the limitation of personal injury and property damage on controlled sites. A tree will not be subject to control if there is little or no chance of damage–unless post-failure cleanup would be more costly than control.

The Field Guide illustrates practical application of the factors involved in hazard rating and control decisions.

DISCUSSION

The Examiners

The hazard examiner requires special knowledge and experience for effective hazard rating and control. He should be trained and qualified to make the decisions required of him. Correct control decisions can limit personal injury and property losses to an acceptable minimum. At the same time they avoid removal of valuable low-hazard trees. An examiner's decision-making skills are enhanced by an appreciation of the basic factors underlying hazard and their effects. Good hazard rating estimates depend on his familiarity with recreation site pathology, his ability to recognize symptoms of tree defect or fault, and to evaluate the resulting loss of stability or strength in trees. In addition, he should be familiar with local weather patterns, and the characteristics of individual sites.

To ensure effective and consistent hazard rating throughout the administrative region, we recommend one of the following options: either (a) teams of specialists in recreation site pathology assigned to cover the entire administrative region and assisted by local personnel selected for their knowledge of local weather patterns and conditions, or (b) frequent training sessions in hazard rating for all personnel assigned to these duties. Considering the periodic reassignment of many personnel, annual sessions may well be required for the latter option.

Esthetic and Cultural Values of Trees

A control decision rule can be devised to weigh the probable losses if a hazard is not controlled against the cost resulting from control. A major factor in such a rule is the value of the tree *in situ*. Valuable specimen trees may warrant retention because of their contribution to the site when less desirable trees with an equivalent hazard rating would be removed.

Such a rule is more difficult to apply–it requires an estimate of the value of the tree or its contribution to the site. Cost-based guides have been developed for shade tree evaluation, and their application to hazard control decisions is being considered by the Pacific Southwest Forest and Range Experiment Station. In the meantime, low-value trees should be given especially careful attention. Their removal may be justified even though their hazard rating falls below

[4] Records derived from over 300 reported accidents occurring west of the Mississippi River during approximately 3 years (1966-1969).

the control level. Conversely, if this rule were applied, high-value trees would sometimes be retained even though associated with high hazard.

Public Responsibility and the Law

It is absolutely possible to limit accidents directly and logically to any desired degree–at a cost. But accidents will occur as long as people and property are exposed to the effects of tree failures. We can only limit the rate of accidents by modifying the acceptable limits of hazard.

Since not all hazardous trees will be removed, we must expect some preventable failures and some preventable accidents on forested recreation sites. A safety standard and hazard control level can set a reasonable upper limit.

Trees rated below this level may still fail, of course. Should one cause an accident resulting in court action, it would provide a situation in which some degree of hazard was recognized but no control was instituted. Of course, this has been happening in the past, but such trees were not recorded. Nor is there any operational necessity for recording a hazard rating unless it falls above the hazard control level requiring future action.

No one can presently foresee a court's reaction to the fact that a continuous range of hazard exists on occupied recreation sites, and that to eliminate all hazard means to remove all people and property or else to do away with the trees. But we may consider the following points: (1) Some predictable hazard is associated with every tree on an occupied recreation site; (2) improved examination and rating procedures with the removal of all hazard rated above the control level would result in a safer environment for the recreationist; (3) the costs or losses involved in removing hazard below the control level are presumably prohibitive; and (4) because people are invited to use a site where hazard exists, we must accept the probability of a certain number of accidents all of which would have been preventable.

If we accept the challenge of providing the best available protection to the public, we must also accept the fact that (recognized) low hazard trees can cause accidents with a risk of official but unjustified embarrassment. It seems a small risk as compared with the opportunity for making significant improvements in public safety and reducing the over-all property losses and personal injuries at reasonable costs.

Failures and accidents may occur without apparent defect or detectable fault in the tree. But hazard can be evaluated for sound as well as for defective trees.

FIELD GUIDE TO HAZARD RATING AND CONTROL DECISIONS

Hazard is rated as the product of the probability of failure, the probability of impact, the damage potential of the possible failure, and the target value. Control is indicated when the hazard rating for an individual tree exceeds an established control level.

The following steps are recommended for rating tree hazard on recreation sites.

Recreationist Occupancy

(1) Select for examination each tree which might pose an appreciable hazard to people or property on controlled sites. (On some sites this may include all trees.)

(2) Examine the tree for defects or faults. (If none is found, pass the tree.)

(3) Estimate the type and intensity of critical weather conditions, depending on the severity of defect or fault, which will result in failure of the tree (e.g., 40-m.p.h. wind).

(4) Estimate the probability of failure in-season (i.e., frequency of critical weather conditions during season that site is occupied by recreationists). For example, an estimated two in-season occurrences in every 10 years or 2/10 = 20 percent probability of failure for one season.

(5) Estimate probability of recreationist occupancy during average season; e.g., 75 occupancy days/100 season days = 75 percent.

(6) Determine damage potential for appropriate tree group and class of potential failure using *table 1* for recreationist occupancy.

(7) Estimate target value (use $4,000 for recreationist occupancy).

(8) Multiply values in (4), (5), (6), and (7) for the hazard rating.

(9) Mark tree for control if hazard rating exceeds the hazard control level.

(10) Examine adjacent trees for any rating change which will result from control of hazardous tree.

Table 1–*Guide numbers indicating relative potential of softwoods and hardwoods for damage to recreationists and their property, by tree size and defect class*[1]

Diameter breast height (inches)	Softwoods		
	Limb	Upper bole	Lower bole, butt, or root
10	–	0.055	0.055
12	–	.065	.065
14	–	.07	.07
16	–	.08	.08
18	–	.09	.09
20	–	.10	.10
22	–	.12	.12
24	–	.13	.14
26	–	.14	.16
28	–	.15	.19
30	0.12	.16	.23
32	.12	.17	.28
34	.12	.18	.33
36	.12	.18	.38
38	.12	.18	.44
40	.12	.18	.49
42	.12	.18	.55
44	.12	.18	.60
46	.12	–	.66
48	.12	–	.71
50	–	–	.76
52	–	–	.80
54	–	–	.84
56	–	–	.88
58	–	–	.91
60	–	–	.94

Diameter breast height (inches)	Oak[2]		Other hardwoods[2]	
	Limb	Lower bole, butt, or root	Limb	Lower bole, butt, or root
10	–	–	–	–
15	–	–	–	0.065
20	0.025	0.10	0.07	.07
25	.06	.10	.08	.10
30	.09	–	.08	.13
35	.12	–	–	.16
40	.16	–	–	.19
45	.21	–	–	.22
50	.27	–	–	–
55	.33	–	–	–

[1] Includes data for pine, fir, Douglas-fir, and the cedar family as well as oak and hardwoods other than oak.

[2] No upper bole recreationist losses reported for oak or other hardwoods. Figures for oak and other hardwoods based on limited data which reflect no injuries or fatalities.

Fixed Property

With valuable fixed property exposed throughout the year, the probable loss may warrant control of hazard. In rating hazard with regard to fixed property, the first three steps are the same as in the procedure used for recreationist occupancy.

(1) *Select for examination each tree which might pose an appreciable hazard* to people or property on controlled sites. (On some sites this may include all trees.)

(2) *Examine the tree for defects or faults.* (If none is found, pass the tree.)

(3) *Estimate the type and intensity of critical weather conditions,* depending on the severity of defect or fault, which will result in failure of the tree (e.g., 40-m.p.h. wind).

(4) *Estimate the probability of failure* during entire year (frequency of critical conditions per year). For example, an estimate of four critical wind storms in 10 years or 4/10 = 40 percent for 1 year. The probability of failure for year-long exposure of fixed property will always equal or exceed that for the shorter period of seasonal recreationist occupancy.

(5) *Estimate probability of impact* for fixed property. For example, the proportion of probable impact arc occupied by fixed property = 20°/ 80° = 25 percent.

(6) *Determine damage potential* for appropriate tree group and class of potential failure using *table 2* for fixed property.

(7) *Estimate target value.* If target would be less than a total loss if struck by a 70-inch d.b.h. softwood, the estimated loss for such an accident is taken as the target value.

(8) *Multiply values in (4), (5), (6), and (7)* for the hazard rating. If tree is also rated for recreationist occupancy, use higher of two ratings.

(9) *Mark tree for control* if hazard rating exceeds the administrative hazard control level.

(10) *Examine adjacent trees* for any rating change which will result from control of hazardous tree.

Table 2–*Guide numbers indicating relative potential of softwoods and hardwoods for damage to fixed property by tree size and defect class* [1]

Diameter breast height (inches)	Softwoods			Diameter breast height (inches)	Oak [2]		Other hardwoods [3]	
	Limb	Upper bole	Lower bole, butt, or root		Limb	Lower bole, butt, or root	Limb	Lower bole, butt, or root
10	–	0.025	0.025	10	–	–	–	0.065
12	–	.03	.03	15	–	.04	–	.065
14	–	.03	.03	20	0.018	.06	–	.065
16	–	.04	.04	25	.025	.08	–	.065
18	–	.05	.05	30	.05	.14	–	.065
20	–	.07	.07	35	.09	.20	–	.065
22	–	.08	.08	40	.12	.29	–	.065
24	0.035	.09	.10	45	.15	–	–	.065
26	.035	.11	.12	50	.17	–	–	.065
28	.035	.12	.14	55	.19	–	–	–
30	.035	.12	.16					
32	.035	.13	.19					
34	.035	.13	.22					
36	.035	.13	.26					
38	.035	.13	.31					
40	.035	.14	.36					
42	.035	.14	.42					
44	.035	.14	.47					
46	.035	.14	.53					
48	.035	.14	.58					
50	.035	–	.64					
52	.035	–	.69					
54	.035	–	.74					
56	.035	–	.79					
58	.035	–	.84					
60	.035	–	.88					
62	–	–	.91					
64	–	–	.94					
66	–	–	.97					
68	–	–	.99					
70	–	–	1.00					

[1] Includes data for pine, fir, Douglas-fir, the cedar family, spruce, and hemlock, as well as oak and hardwoods other than oak.
[2] Insufficient data for upper bole. Suggest using limb values for oak upper bole.
[3] Insufficient data for limb and upper bole.

Tree No.	Occupancy	Species group[1] and d.b.h. (inches)	Potential failure class	Probability of tree failure		Probability of impact		Damage potential guide number		Target value[2] (dollars)	Hazard rating	Control recommended
				In season	Annually	Human occupancy	Fixed property	Human occupancy	Fixed property			
1	lavatory	S(40)	limb	0.10	—	0.80	—	0.12	—	4,000	38	
2	service building	H(30)	root	—	.60	—	.40	—	.065	800	12	
3	sign	S(24)	butt	—	.90	—	.90	—	.10	100	8	
4	pumphouse	S(36)	limb	—	.70	—	.80	—	.035	500	10	
5	recreationist	H(34)	lower bole	.70	—	.40	—	.16	—	4,000	179	✓
"	unit property	"	"	—	.80	—	1.00	—	.065	500	26	
6	recreationist	H(25)	lower bole	.40	—	.50	—	.10	—	4,000	80	
7	recreationist	S(18)	butt	.60	—	.70	—	.09	—	4,000	151	✓
8	recreationist	S(28)	limb	.10	—	.70	—	.12	—	4,000	34	
9	summer residence	S(24)	butt	.40	—	.90	—	.14	—	4,000	202	✓

[1]S = softwood; O = oak; H = other hardwoods. [2]Human occupancy = $4,000.

Figure 1–*A worksheet illustrates the use of the field guide in rating tree hazard with the hazard control level = 100.*

Worksheet

A worksheet *(fig. 1)* illustrates use of the guide with a hazard control level set at 100. A worksheet may not be needed in practice since the simple multiplication can be done on scratch paper. Tree 1–a 40-inch d.b.h. ponderosa pine–was examined because it is in position to threaten a lavatory.

- A defective limb was found. Since the lavatory is used seasonally and exposed throughout the year, two ratings are possible but hazard was rated only for human occupancy.
- Probability of failure in-season was estimated at 10 percent (0.10).
- The examiner estimated that the lavatory would be used 100 days of the 125-day season. Probability of impact (recreationist occupancy) = 100/125 = 80 percent (0.80).
- The damage potential of a ponderosa pine limb is 0.12 for recreationist occupancy *(table 1).*
- The target value is $4,000 for recreationist occupancy.
- The product of the four values (0.1 X 0.8 X 0.12 X $4,000) to the nearest dollar is $38 and does not exceed the hazard control level of $100.
- Decision: no control recommended.

A tree threatening a unit subject to recreationist occupancy should first be rated for this situation. The rating for fixed property occupancy is usually lower, and will not ordinarily be needed if hazard has been rated for recreationist occupancy. In unusual situations, making both ratings may compensate for the extra costs of inspection.

Trees 2, 3, and 4 require only a fixed property rating if human occupancy is considered minimal.

SUMMARY

Paine, Lee A.
1971. **Accident hazard evaluation and control decisions on forested recreation sites.** Berkeley, Calif., Pacific SW. Forest & Range Exp. Sta., 10 p., illus. (USDA Forest Serv. Res. Paper PSW-68)

Oxford: 907.2:304: 416.
Retrieval Terms: forest safety; hazard evaluation; accident prevention; recreation sites; dangerous trees; defective trees; recreation site pathology.

This paper reports a study of the factors in recreation site hazard and the problems in providing an acceptable level of public safety. It defines, for the first time, the factors involved in accident hazard associated with trees and their interrelationships, and provides a practical method for hazard evaluation. Data for the study were supplied by cooperating public agencies.

The goals were to (a) define the major factors contributing to hazard on forested recreation sites, (b) interpret the interrelationships of these factors and their effects on hazard, (c) develop experience tables which would permit realistic appraisal of hazard, and (d) design a practical guide to hazard rating and control decisions for field examiners.

Hazard is defined as the expected loss from mechanical failure of a tree during the current inspection cycle–unless the probability of an accident is reduced. Thus hazard may be expressed in terms of dollars. The major contributing factors include the probabilities of mechanical failure and of target impact if failure occurs, the damage potential of the failure, and the value of the target. Hazard is directly related to each of these four factors, and may be evaluated as their combined product. Tables on damage potential for recreationist occupancy and for fixed property permit a direct field rating of hazard.

The field guide included in this paper provides an orderly consideration of each of the factors involved in hazard and a numerical rating of the individual tree being inspected. Control decisions are based on a comparison of the individual hazard rating with a hazard control level that is administratively pre-set.

Tree No.	Occupancy	Species group[1] and d.b.h. (inches)	Potential failure class	Probability of tree failure		Probability of impact		Damage potential guide number		Target value[2] (dollars)	Hazard rating	Control recommended
				In season	Annually	Human occupancy	Fixed property	Human occupancy	Fixed property			

GPO 980-763

The Forest Service of the U.S. Department of Agriculture

. . . Conducts forest and range research at more than 75 locations from Puerto Rico to Alaska and Hawaii.

. . . Participates with all State forestry agencies in cooperative programs to protect and improve the Nation's 395 million acres of State, local, and private forest lands.

. . . Manages and protects the I 87-million-acre National Forest System for sustained yield of its many products and services.

The Pacific Southwest Forest and Range Experiment Station

represents the research branch of the Forest Service in California and Hawaii.

Paine, Lee A.
1971. **Accident hazard evaluation and control decisions on forested recreation sites.** Berkeley, Calif. Pacific SW. Forest & Range Exp. Sta., 10 p., illus. (USDA Forest Serv. Res. Paper PSW-68)

Accident hazard associated with trees on recreation sites is inherently concerned with probabilities. The major factors include the probabilities of mechanical failure and of target impact if failure occurs, the damage potential of the failure, and the target value. Hazard may be evaluated as the product of these factors; i.e., expected loss during the current inspection cycle unless hazard is reduced. A practical approach to hazard rating is described. Tables on damage potential for recreationist occupancy and for fixed property are included in the field guide.

Oxford: 907.2:304 :416.
Retrieval Terms: forest safety; hazard evaluation; accident prevention; recreation sites; dangerous trees; defective trees; recreation site pathology.

Paine, Lee A.
1971. **Accident hazard evaluation and control decisions on forested recreation sites.** Berkeley, Calif. Pacific SW. Forest & Range Exp. Sta., 10 p., illus. (USDA Forest Serv. Res. Paper PSW-68)

Accident hazard associated with trees on recreation sites is inherently concerned with probabilities. The major factors include the probabilities of mechanical failure and of target impact if failure occurs, the damage potential of the failure, and the target value. Hazard may be evaluated as the product of these factors; i.e., expected loss during the current inspection cycle unless hazard is reduced. A practical approach to hazard rating is described. Tables on damage potential for recreationist occupancy and for fixed property are included in the field guide.

Oxford: 907.2:304 :416.
Retrieval Terms: forest safety; hazard evaluation; accident prevention; recreation sites; dangerous trees; defective trees; recreation site pathology.

Paine, Lee A.
1971. **Accident hazard evaluation and control decisions on forested recreation sites.** Berkeley, Calif. Pacific SW. Forest & Range Exp. Sta., 10 p., illus. (USDA Forest Serv. Res. Paper PSW-68)

Accident hazard associated with trees on recreation sites is inherently concerned with probabilities. The major factors include the probabilities of mechanical failure and of target impact if failure occurs, the damage potential of the failure, and the target value. Hazard may be evaluated as the product of these factors; i.e., expected loss during the current inspection cycle unless hazard is reduced. A practical approach to hazard rating is described. Tables on damage potential for recreationist occupancy and for fixed property are included in the field guide.

Oxford: 907.2:304 :416.
Retrieval Terms: forest safety; hazard evaluation; accident prevention; recreation sites; dangerous trees; defective trees; recreation site pathology.

Paine, Lee A.
1971. **Accident hazard evaluation and control decisions on forested recreation sites.** Berkeley, Calif. Pacific SW. Forest & Range Exp. Sta., 10 p., illus. (USDA Forest Serv. Res. Paper PSW-68)

Accident hazard associated with trees on recreation sites is inherently concerned with probabilities. The major factors include the probabilities of mechanical failure and of target impact if failure occurs, the damage potential of the failure, and the target value. Hazard may be evaluated as the product of these factors; i.e., expected loss during the current inspection cycle unless hazard is reduced. A practical approach to hazard rating is described. Tables on damage potential for recreationist occupancy and for fixed property are included in the field guide.

Oxford: 907.2:304 :416.
Retrieval Terms: forest safety; hazard evaluation; accident prevention; recreation sites; dangerous trees; defective trees; recreation site pathology.