Santa Clara County
Department of Parks and Recreation

Tree Safety Program
Field Manual

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INTRODUCTION

Santa Clara County Department of Parks and Recreation manages various properties along the entire spectrum of recreational opportunities from remote areas, with little human impact, to urban environments, with heavy visitor use and impacts. Trees are a vital part of our park ecosystems and are particularly important for shading and screening in high use recreational facilities and staging areas. The purpose of this program is to manage vegetation in those areas most impacted by human activity, in a manner that promotes human safety, conforms with Department natural, cultural and historical resource protection policies and strives to protect property on a site-by-site basis. These developed areas constitute, what can be called, an altered environment in which the landscape, soils, and vegetation have been altered to some extent for the purpose of access or recreational opportunity.

The Department is dedicated to the philosophy that native trees will be left in their natural condition (where that condition still exists) and will not be managed on an individual tree-by-tree basis. Concurrently, the Department recognizes the inherent conflicts between public access and use and the natural condition of trees, as they are not permanent features in the environment, particularly in developed areas where park facilities and the accumulative impact of visitor use may have a negative impact on park trees. As such, the department will reasonably manage trees, particularly in developed areas, necessary to sustain their health, maintain a representation of the natural ecosystem, identify and minimize problems that might result in tree failure, visitor and/or park staff injury, and/or property damage. The following guidelines will aid the department:

- Protect natural woodland communities,
- Maintain a representation of the natural setting,
- Manage problem trees in designated developed areas that are characterized by high public use, prolonged, stationary visitor uses (picnic areas, campgrounds, staging areas, etc.), and
- Protect park facilities and cultural and historical resources.

Hazardous Tree Program Guidelines

The department will take every reasonable precaution to reduce potential sources of injury to persons and damage to property from falling trees or their parts in all areas where visitors and park staff congregate and remain stationary for periods of time. There shall be a program consisting of a systematic effort to detect and manage, insofar as possible, hazardous conditions resulting from the presence of structurally compromised trees or tree parts in areas frequented by park users or staff. This hazardous tree program shall have a process and procedure for detection, monitoring and evaluation, and shall be documented. The Parks Natural Resource Program Supervisor or his/her designee shall maintain this documentation.

A formal, safety inspection of all trees in each public use and administrative area, designated within the program description, within the Santa Clara County Park system shall be inspected by trained Park Natural Resource Program staff on a bi-annual basis.

The formal inspections will be augmented through informal observations by trained park unit staff designed to identify and report sudden changes in trees, which could result in an increased hazard to the visitors and staff.

Any developed area within any park unit that has experienced a major wildfire or windstorm shall be temporarily closed until trained staff accomplishes an ad hoc inspection. The purpose is to locate and remove trees or tree parts that have become structurally unsound as a result of the disturbance.

Records shall be maintained per the Department Data Management Policy (EDMS, 2002). Complete records of all inspections shall be made on approved forms only and include:

- Date of inspection,
- Dates of control actions, and
- Name and title of personnel conducting the inspections.

The liability and responsibility for the management of hazardous tree conditions must be discharged in the same manner on all park system lands. Parklands relating to areas of public use and occupancy, whether such areas are themselves operated by the County Park Department or on private lands adjacent to Department operated lands.

The removal of trees or parts of trees can have a detrimental impact to park values. It is imperative that every inspection and decision be made by professionally trained Park personnel who is competent to judge both the degree of risk and the probable effect on park values of tree (or parts of trees) removals.

Identifying Hazardous Trees:

1. The Natural Resource Program will use a GIS map, park brochure or other maps to identify use areas, leased properties, residences and other areas where people congregate that require tree management. These management zones will follow defined parameters through approved Natural Resource Plans, Strategic Plans, Master Plans, management prescriptions for specific species management, ecosystem or unit will also be followed as they apply to specific park trees and forest areas. Park facilities without such plans will have approved Facilities Unit vegetation Management Plans or action plans that address vegetation management strategies within use areas.

Natural Area Management Zones: In general, native trees in natural units will not be managed, but will be left in their natural condition. Trees in recreation and

historical/cultural zones will be managed, when required, to achieve identified resource and safety objectives.

2. The natural resource program will initiate and maintain a conscientious and systematic program of hazardous tree inspections within designated recreation areas for the purpose of identifying and addressing tree problems in these developed public use areas. The inspection of hazardous trees serves 3 major purposes: 1) identify in a timely manner problems that are weakening the tree(s), and, when appropriate, taking steps to keep park trees healthy and vigorous, 2) identify and eliminate conditions that would result in tree failure, thereby reducing potential for injury to the tree itself, injury to park users, or damage to property; 3) provide documentation for tree maintenance work, as well as removal of potential hazardous trees required for a reasonably safe park environment. The Natural Resource Program Supervisor, or his/her designee, will be responsible for implementing the tree inspection program that will involve the following components:

   a) Trained Natural Resource Management Technicians will conduct a bi-annual (fall/winter) inspection using the Department's Hazardous Tree Inspection Form for trees in designated areas. Suspected problem trees will be marked with a small numbered tag. Park Maintenance Leads and selected Operations staff will be provided training sufficient to accomplish informal inspections between the bi-annual formal inspections conducted by Trained Natural Resource Management Staff.
   b) A contracted Arborist may be sought, at the request of the Natural Resource Program Supervisor, to inspect any "borderline" trees or "valued" trees that may require additional surveys. Valued trees may be historical, cultural or natural resource significance.
   c) Identified high-risk trees that fail should be reported to the Natural Resource Program Supervisor who will investigate, potentially with other natural resource program staff, State Park Forester or consulted arborist, before the tree is removed to document the cause(s) of failure and report. If injury or property damage occurs, immediate notification to the Natural Resource Program Supervisor, Park Ranger Operations Manager and Park Maintenance Operations Manager.

3. The Department will implement a tree removal review process to ensure that recommendations to remove trees is justified and that the appropriate individuals and involved parties have been informed and consulted. The Natural Resource Program Supervisor has the authority to remove trees that are deemed a hazard, or that meet vegetation management criteria for the benefit of ecosystem or forest health, that are not unique, are not nests sites for raptors or other protected species, or are not special features in the Park setting. Trees that fall under the jurisdiction (and circumstances) of the Tree Ordinance must have Santa Clara County Board of Supervisor's approvals for removal.

The Department will use the following review process to make the decision to remove a unique tree or group of trees. The following steps will be taken by the Park Natural Resource Program Supervisor to obtain required authority to proceed:

> **Step 1:** the joint recommendation of the Natural Resource Technician and Natural Resource Program Supervisor will be presented to the Park Maintenance Operations Manager. If approvals are granted and further review is not required, permission will be granted by the Maintenance Manager. If further review and consultation is required the Natural Resource Program Supervisor will contract and consult with an Arborist or California State Parks Forester charged with implementation of the State Park Tree Safety Program.
> **Step 2:** following a reasonable consultation period, the Park Maintenance Manager will consider the matter again. If under the authority of the Maintenance Manager and no further approvals are required, notice to proceed will be granted. If a decision is agreed to not proceed, the recommendation will be presented to the Maintenance and Operations Deputy Director for a final decision.

4. Where non-native trees within recreation and staging areas demonstrate a high-failure rate, they will be considered to be replaced, if feasible, with appropriate native trees fitting of the park setting and capable of withstanding the high use impacts of the public. In certain situations, it may be feasible to relocate facilities and save trees with minor pruning or other mitigation applications.
5. The Department will undertake a planting program to replace removed or lost trees within recreation and staging areas. For areas where irrigation is possible and planting plans of some sort exist, native stock (to retain genetics) should be first consideration, if not feasible, trees will be purchased in 5 to 15 gallon containers and replanted. If irrigation is not available or a plan does not exist, the facility Vegetation Management Plan format will be used and go through the appropriate County Park approval process. The Unit Park Maintenance and Park Ranger Supervisors will be responsible for getting the replaced trees in the annual budget and installation and maintenance throughout the establishment period.

Field Procedures

The site inspections must be conducted in a systematic manner to ensure that all trees capable of striking target areas are inspected. Inspect only trees 6” or greater in diameter.

a) Identify Target Areas: These include areas that visitors (and their possessions) are encouraged to occupy such as tables, stoves/firepits, benches, parking areas, reasonably flat areas devoid of obstacles such as vegetation, rocks and debris. Includes any tree that would strike the target if they fail. Estimate the height of dominant trees around the targets to determine how far into the canopy to inspect; the height of the dominant trees is the distance back from the targets that must be examined. Note landmarks that will serve as boundaries of the inspection areas.

b) Systematic Inspection: Visit every tree that is capable of directly striking the target area. Methodically examine all parts of the tree on all sides. Begin at the base of the tree and work upward.
c) If there are no significant defects present, proceed to the next tree.
d) If there are significant defects present, complete the tree inspection form, following these steps:
    a) Tag the tree with a numbered tag. Place the tag on the side of the tree that faces the fixed reference point. Place the tag as high as possible on the tree.
    b) Note tag number on the form.
    c) ID tree species, using the first letter(s) in the common name.
    d) Measure the DBH. Adjust height of measurement to avoid deformities, swellings and branches. Estimate tree height. Measure to the nearest inch. For multiple trunked trees branching below 4', measure each trunk. If the separation is at or near ground level, tag and assess as separate trees.
    e) ID the target type the tree would hit if failure occurs. Rate the target for occupancy rate.
    f) Describe all significant tree defects, beginning at the base of the tree and work upwards, including soil conditions, wind exposure as most tree failures are associated with high winds, major pests or diseases problems that might influence tree vigor and development of hazards (infestations of mistletoe, bark beetles or aphids have little affect on tree stability).
    g) Rate the size and location of the defective part. The larger the part that will fail and/or the higher up in the tree it is, the greater the potential for damage
    h) ID treatments to abate the hazardous situation.
    i) Continue in a logical fashion around the target area, examining trees and assessing this with significant defects.

Consultation with an Arborist

When all of the trees in the target area have been inspected. Contact the NRM Program Supervisor for determination of the need for a site visit by a contracted Arborist or State Park Forester.

If during the course of the assessment, a tree is deemed to be an imminent danger of failing, the area shall be secured and closed by Park Ranger staff and the appropriate Chain-of-Command shall be notified immediately, including the NRM Program Supervisor.

Schedule of Mitigation Work

Trees with the highest rating shall be treated as priority treatments. The NRM program Supervisor will work with Park Unit Maintenance staff and Supervisors to authorize contracted tree treatments. In this cases where Park staff can conduct recommended mitigation, it will be coordinated through the Park Unit Park Maintenance Supervisor.

Provided recommended mitigation will be noted on the inspection form and dated and initialed by the person conducting the mitigation or project lead in the case of contracted corrections. Tags will be removed from treated trees and returned to the Natural Resource Program.

Make note of any changes that may occur throughout the year and/or when informal inspections occur or indicate changes that had occurred. Records shall be maintained per the County Park retention policy (EDMS policy)

GOALS AND OBJECTIVES

- Provide a reasonable standard for public safety regarding hazardous tree management, based on industry standards (California State Parks, East Bay Regional Park District).
- Establish and maintain historically authentic landscape vegetation in the primary historic zones of all park units.
- Acquaint the public with native vegetation ecotypes and communities. Vegetation is manipulated to maximize the similarity/representation with the surrounding unaltered forest community (in terms of species composition and structure)
- Provide the basis for preparing site vegetation management plans for visitor use areas; to be related to approved park unit natural resource management plans. Prior to such plans the information can be used as a guideline to management of visitor use areas. Following adopted natural resource plans, the information can be used as the baseline to address needs related to visitor impacts and use to the management of the natural resources.
- Re-establish trees in areas where human use has reduced tree cover and associated community associations.

SCOPE

Typically the boundary between developed areas and wildland areas is indistinct. Contemporary urban born visitors to parks may have a strong tendency to remain within the comfortable boundaries of developments, including marked roads and trails. Only a small portion of park visitors will venture into a trail-less, roadless wildland. Thus visitors use ranges from very high within the facilities area and falls off dramatically away from developments. Since the transition from development and wildland is gradual and has no distinct boundary, an arbitrary decision based upon liability was made to define the limits of a facility area. The vegetation limits of a development are the distance radially out from the edge of a significant target equal to the potential height of the mature trees (i.e., trees that are capable of reaching the target). This program manages vegetation that is within this liability perimeter around the facilities, which is defined as concentrations of employees and visitor use for a period of time. For example:

Included	Not included
♦ Residences (permanent or mobile) ♦ Administrative Areas including utility installations ♦ Public use areas including concessions ♦ Improved areas with trees tall enough to reach adjacent private facilities ♦ Private property with trees tall enough to reach park facilities or visitor use areas described within (notification to the private property owner).	♦ Natural Areas ♦ Trails (hiking, horse, bike, multi-use, special use, etc.) ♦ Roads (improved or unimproved)

ADMINISTRATION

Program Responsibilities

Park Maintenance Division

The Department Natural Resource Program is responsible for the program policy and implementation. This requires the Park Natural Resource Program Supervisor, and designated Natural Resource Technician, maintain a competency equivalent to the California State Park training standards for those hazardous tree assessments to minimize the Department's risk in tort liability and to conduct forest manipulations as required. Parks Natural Resource Program staff charged with implementation, and informal training of park unit staff, must be trained and certified by a California State Park Forester certified to train to industry standards. Trained Natural Resource Program staff must train and certify those participating in the informal inspections in order to maintain County Park system-wide consistency and proficiency in program implementation. Trained and certified Natural Resource Program staff must investigate all injury or fatality incidents on department property related to tree failures since these incidents are likely to result in litigation against the department. The Parks Natural Resource Program designee must keep abreast on current research in Forestry and Arboriculture, update the department's policy and procedures as necessary and provide assistance to field staff regarding arboricultural care, vegetation management and contracting.

Park Unit Maintenance

Park Maintenance Lead staff shall be the Park Unit designate to participate in training and informal inspections. The Park Unit Maintenance Lead is responsible for retaining consistency and competency in the hazardous tree program implementation. The Park

Maintenance Lead will maintain records of informal inspections and forward all written records to the Park Natural Resource Program Technician charged with implementation of the Hazardous Tree Program. The Park Maintenance Lead may be asked to cooperate, monitor and participate in overview and taking action on specified trees, when safe and appropriate.

Park Operations Division

Park Ranger staff, through Park Ranger Operations Chain-of-Command, must take action on those aspects of the program of an immediate emergency or resource protection concern. This includes closure of park facilities for reasons of hazardous conditions and investigation of injury and damage incidents. The Park Ranger must notify his or her Chain-of-Command and the Park Natural Resource Program Supervisor in the event of a tree failure that causes human fatality or serious injury on department property. The area of the tree failure incident must be treated as a crime scene and not disturbed until the incident can be properly documented.

Training

Employees responsible for administering the program must receive training in risk analysis of individual trees, and mitigation of hazardous conditions. The training is consistent with California State Park tree safety program standards, and is divided into three parts:

- Reading
- Classroom presentation, and
- Field experience

Upon completion, the trainee(s) will be certified by California State Park Forester to administer the program anywhere within the County Park jurisdiction unless restricted certification is specified.

Objectives

The intent of this program is public health and safety, so the objective of training is the recognition and mitigation of hazardous conditions of trees. However, since vegetation management is at the core of the Department's natural resource program there shall be an emphasis on vegetation management consistent with approved park unit natural resource management plans. The emphasis on vegetation management shall not eliminate the need for safety; rather it addresses additional objectives of maintaining the historic vegetation or managing to mimic the native woodland community in perpetuity. Consequently, a secondary training objective is to recognize when a comprehensive vegetation management approach is warranted.

The individual tree risk assessment-training component is standardized consistently with California State Park's tree risk assessment, such that it is defensible in litigation proceedings. The tree risk assessment training focuses on:

1. Objective recognition and mitigation of a high risk condition;
2. Proper arboricultural practices in order to maintain the health and longevity of the existing trees;
3. Contract specifications and administration since many of the actions taken (pruning, removal of dead limbs, felling, etc) will be completed by contract; and
4. An understanding of the effects of an urban environment on the health of trees and other plants.

Santa Clara County Department of Parks and Recreation has numerous forest and woodland communities and it is impractical to attempt to understand natural community dynamics for each one and the effect of developed facilities on those communities. Orientation training in woodland and forest community management shall utilize approved park unit natural resource management plans and park master plans, when available. If not available, the orientation training shall utilize the park's natural resource inventory and park inventories of facilities and development areas. The trainee shall be able to monitor the woodland and forest communities and determine whether past practices, development and use impacts have caused significant changes in the composition and structure.

Required Reading

- Hazardous Tree Program: Policy, Administration and Standards.
- An approved Park Unit Natural Resource Management Plan and Park Master Plan, if available.

Classroom

The classroom training consists of Microsoft PowerPoint presentations on several subjects:

1. Liability
2. Tree Architecture
3. Compartmentalization Of Decay In Trees (by Alex Shigo)
4. Structural defects
5. Inspection procedures
6. Thresholds and Mitigations
7. Construction Near Trees

Field Experience

Field training in tree risk rating and control will be accomplished during normal bi-annual park unit inspections. The training requires adequate coverage of tree species,

defects, pest species, and site situations that represent typically encountered situations of the County Park system.

Inspections

Procedure

The type of survey that is performed depends on whether an approved park unit natural resource management plan is available. If no plan exists, than the standard tree-by-tree risk assessment for all appropriate sites must be completed bi-annually. If a natural resource management plan is in effect for the area (with associated vegetation management plan for developed areas), then the site must be sampled to determine what vegetation manipulations are required. Every tree must then be examined for safety and other natural resource management objectives at least every five (5) years.

The standard risk rating analysis is conducted to assure that all trees affecting a site, and all portions of each tree are inspected. An individual examination of each tree should be conducted in a systematic fashion around each target area. Examine each tree in order of decreasing risk: 1) roots, 2) lower bole, 3) upper bole, and 4) crown.

Root Crown Inspections

Root crown observations should be made by removing the soil around the trunk to expose the original roots from the root flare. Care should be taken to pull dirt away from the roots rather than risk injury to the roots by driving a tool into the soil. Soil embedded in the coarse bark of the trunk can be removed with a paint scraper. This will also effectively remove rotted bark to the live phloem, if it exists. If decay or disease is found, an assessment of the extent of decay can be made and recommendations and treatment developed. Healthy roots should be recovered with soil to the original grade but infected areas should be left exposed.

Personnel

Formal Inspections shall be performed bi-annually by the Parks Natural Resource Program Supervisor or his/her designee who is responsible for the Hazardous Tree Program implementation (Inspections must be performed by trained personnel).

Tools and materials

- Chisel edge geologist's hammer
- Diameter tape
- Clipboard
- Binoculars, monocular, or range finder
- Hand compass
- Increment borer or portable electric drill with ____ bit
- County Park Hazardous Tree Program forms

- Pre-numbered tags and nails
- Blue tree paint
- "Caution" Ribbon to close site
- Camera

Reference Information

- Occupancy figures for all park unit campgrounds and day use areas, as available.
- Hazard rating and control table for recreationist occupancy and fixed property.
- Contract specifications for tree treatments.
- The approved vegetation management plans for the area, as available.
- Monitoring data collected to evaluate the condition of the forest community in relation to the vegetation management plan.
- Aerial photography

Documentation

All trees scheduled for work shall be marked with a number on their trunk (pre-stamped tag) and shall be located by distance and compass bearing from a permanent fixture. This information shall be recorded on appropriate forms. Tags should remain on trees until all control work shown on the most recent County forms has been completed.

A negative report shall be entered on all appropriate County forms if no high-risk trees were found in a facilities area. For example, "Valley View I Campground-No hazards found". This action is necessary to document compliance with the program.

Sensitive Wildlife Species

State or federally listed animal species may inhabit individual trees within a developed area. If the tree is identified for tree work (including removal, trimming, pruning or bracing) this action may adversely impact the animal(s). Alternatives will be sought and reviewed prior to treatment. Area may be closed (or access restricted) if wildlife in question uses the tree designated for treatment seasonally or part of the year (e.g., nesting, breeding, foraging, etc.). All consideration will be provided to limit impact to the designated species without jeopardizing visitor or employee or property.

Tort Litigation

Most tree failures that cause injury or property damage on Department lands will result in some type of claim being filed against the Department and/or County. County Risk Management and County Counsel usually handle monetary claims for property damage. When a serious accident involving personal injury occurs a tort claim will likely be brought against the department for medical care reimbursement and pain and suffering damages. County Counsel assists the Parks Department for tort claims.

The ability of the County to successfully defend against serious tort litigation depends, in part, upon the County Parks Department's post accident investigation. Whenever a tree failure on Parkland results in injury, Park Ranger staff shall immediately contact the Parks Natural Resource Program Supervisor and should treat the scene as if it were a sensitive crime scene (take still, date stamped photographs and restrict access to the failure site). The tree parts shall be moved as little as possible prior to the Natural Resource Program Supervisor examination of the scene, and the taking of video and still photographs. All photographs and video recordings should be documented with date and time, preferably directly on the exposure.

During discovery, depositions and court proceedings, plaintiff's attorneys will request information on how the Department is complying with its Hazardous Tree Program. Completed copies of the Department's Hazardous Tree forms are essential to document program compliance. If this documentation is lacking or incomplete, the plaintiff's counsel can subpoena employees to testify about their recollection of tree removal activities during the subject time period. This wastes valuable staff time, is often less accurate, and places the department in an unfavorable position with respect to the outcome of the litigation.

Funding

The hazardous tree assessment program is funded out of object II Natural Resource Management Budget. The corrective measure aspect of the tree program is funded in the Manager of Park Maintenance Services budget. Tree work is justified on the basis of safety and is thus fully funded. Most of the tree work is assessed via the tree-by-tree risk rating system conducted for each facilities area bi-annually.

When a major portion of the forest community of the facilities area is stressed, unstable, or is no longer representative of the native ecosystem, and cannot be successfully managed via a tree-by-tree risk assessment, a vegetation management plan for the facilities area of that Park Unit shall be developed to determine long-term management goals. Priority tree work in locations where these plans are approved is based on safety and the degree of disparity between the current conditions of the forest community, or tree associations, and the desirable conditions. Once the plan becomes operational, there will be a phased-in period where corrective manipulations are performed at least every two years to create the desired forest composition and structure. When the desired community composition and structure is attained, budgeting can be shifted to a 5 year cycle, where minor corrective action are conducted to maintain the desirable attributes of the forest community.

Tree Risk Rating

Hazardous tree evaluation is the systematic process of assessing the potential for a tree or one of its parts to fail and, in doing so, injure a park visitor or employee or damage property. All trees have the potential to fail. The degrees of hazard will vary with size of the tree, type and location of the defect, tree species, and the nature of the target. It is

not designed to evaluate tree health or stability of the forest community. The motivating force behind the tree risk rating system is Department and County liability. The formal process must be able to (based on history and experience of the California State Park Tree Safety Program and East Bay Regional Parks Hazardous Tree Program):

1. Detect structural conditions in trees that have a high probability of causing human injury or property damage;
2. Record all tree hazards detected;
3. Mitigate these situations; and
4. Preserve all records of these actions.
5. The tree risk rating process is a tree-by-tree assessment of the likelihood of tree failure causing human injury or property damage.

The Hazardous Tree Assessment involves three primary components:

1. A tree with the potential to fail,
2. An environment that may contribute to that failure, and
3. A person or object that would be injured or damaged (I.e., the target).

In most cases tree failures do not occur at random, and in many cases the factors that lead to failure can be observed. Most tree failures appear to involve specific defects of structure such as the presence of decay. These defects are more likely to result in failure under certain environmental conditions such as saturated soils, strong winds and heavy rains. The most likely failure situation involves a combination of structural defects and unusual or severe weather.

Individual tree species have common ways in which they fail that involve both structural defects and environmental factors. Knowledge of these species-specific failure patterns gives an evaluator another tool in rating hazards. For example, in oak trees wood decay is associated with over 75% of all failures. In these species, looking closely for and noting the presence of decay is a key element in rating hazards. In contrast, failure in Monterey Pines is not usually associated with decay. In this species, most common failure profile is heavy, horizontal limbs in high winds.

The California Tree Failure Report Program, cooperative effort between the UC Cooperative Extension and arborist in California, has developed much of the information about failure patterns. Detailed observation about failures is reported by arborist and compiled by the project. Information about the program is found in Appendix E.

Objectives

1. Rank the hazards and establish priorities of control;
2. Establish an objective uniform level of risk management control throughout the County Park system;
3. Enable the Parks Department to establish safety goals and standards against which to measure the performance of the Hazardous Tree Program;

4. Provide information about marginal trees; and
5. Model the Hazardous Tree Program to the California State Park system's Tree Safety Program in order to establish industry standards and provide training requirements.

A quantitative tree risk rating system should be applied to all trees if it is to be objective, however this is not practical over large land areas. Fortunately, the Department can limit the number of trees that are formally rated without compromising the value of the system or the level of safety, given several assumptions:

1. The vast majority of live and dead trees on Department parklands are located in places where the public does not often visit nor are there any significant developments. Here risk is negligible, so these trees need not be rated.
2. It is Department policy to immediately remove all dead trees capable of falling on significant targets; so dead trees within facility areas should not be rated.
3. The tree risks rating system is a valuable training tool. It objectively focuses a trainee's attention on the critical factors affecting risk. The trainee should use the system extensively during the first few days of field inspections. With practice, the trainee will soon recognize low risk defects and high-risk situations without the aid of the formal rating system. If it is obvious that the only way to mitigate the problem is by way of removing the entire tree, then a formal rating is not necessary.
4. The risk rating is a valuable piece of information for any tree for which the probability of injury or damage is of significant concern to the inspector. The inspector shall locate and formally rate any live tree that has a significant target and is currently in a marginal structural condition, regardless of whether the hazard rating exceeds the threshold value or whether the condition is mitigated.
5. Risk rating is not necessary for vegetation management activities, which are designed to be preventative, or for pruning and cabling of a valuable tree in order to prolong its life.

Recognizing Risk

Trees cannot be separated into hazardous and non-hazardous groups. Every tree has some potential to cause human injury or property damage due to failure. The inspector must select only those trees that have a statistically higher probability of causing damage to property or injury to persons. This includes an analysis of the target area, site conditions, and on the tree itself.

The risk rating is derived by adding values estimated for four critical factors:

Risk = Target+ Occupancy + Size of Failed Part + Failure Potential

Target

This category assigns a value to the target that would be injured, damaged or destroyed by a failed tree or tree part. If the target is property-only, then the category is assigned

by comparing the estimated target damage to the cost to prevent the damage. Consider that the average useful lifespan of a tree in a developed area is significantly longer than the operational time span of most pieces of property, so trees should not be removed or wounded to protect inexpensive or short-lived replaceable property. It is often easier and cheaper to replace the property than the tree. Target Values are assigned as follows:

0. If the total value of the property-only target is less than or equal to the cost of mitigation then it is cheaper to replace the target than to work on the tree. Thus this situation is assigned a zero (0) value denoting that no action is necessary, even if other categories are assigned higher values.

1. If a property-only target has more value than the cost of mitigation and the estimated property damage from the failure is somewhat greater than the cost of mitigation, this situation is assigned a Target Value of one (1)

2. If a property-only target has significantly more value than the cost of mitigation and the estimated loss from the failure is significantly greater than the cost of mitigation, this situation is assigned a Target Value of two (2). Animals as property (e.g., horses) are included in this category value.

3. If the target is human-only or human plus property, the category is given the highest Target Value: three (3). The target is considered human if humans frequent the area or remain in the target zone for extended periods of time.

Occupancy

The probability of target impact when a tree fails is actually a joint probability that: 1) the falling tree or tree part will strike a specified area; and 2) that the valuable target will be present in the area. The Occupancy Value is calculated differently for mobile targets such as humans and their possessions versus fixed property such as buildings and other structures. Occupancy Values are as follows:

0. A zero (0) Occupancy Value is assigned for occupancy rating of ≤1 %. The zero (0) value denotes that no action is necessary even if other categories are assigned higher values.

1. Occupancy ≥ 2 % & < 25%

2. Occupancy = 25 – 50 %

3. Occupancy > 50 %

Mobile property and Human occupancy

Trail

Hiking/equestrian/bicycling trails are considered too low in usage to warrant inspecting. For example, assuming that people passing through an area are walking slowly @ 1 mile per hour (including brief stops). These visitors would cover 5280 feet in one hour. Assuming that any point along that trail is defined as a 2-foot section of trail, that being equal to the width of a person, this translates to .0378 % occupancy. Therefore in order for any point on the trail to be occupied 1 % of the time, 26 people would have to walk through that point in one hour; or 624 people would have to walk through that point in a 24-hour day; or 227,760 people would have to walk through that point in a year. This is considered unlikely for the vast majority of trails in the park system.

Although equestrians generally move faster than hikers the target area represented by a horse and rider is larger than a single human, so the two factors cancel each other to arrive at approximately the same occupancy rating. A bicyclist presents a slightly larger target than a single hiker. However, bicycles move significantly faster than a hiker so the occupancy of a single bicyclist is lower than a hiker.

In order for a mobile property such as a vehicle to achieve a 1% occupancy the property would have to be present in the target zone for more than 87 hours per year. This is likely in a designated day use parking lot, but unlikely on a park road.

Areas of Congregation

The term “target area” denotes the general area surrounding centers of visitor activity such as the camp or a picnic table, stove, tent site, cupboard, and parking spur, where the visitors tend to congregate, sit, or recline for longer than brief periods of time. Not included would be points visited briefly such as water faucets, refuse containers, and areas along roads and trails remote from the above-mentioned target areas.

For human occupancy, the probability of impact and the probability of occupancy may be considered synonymous. In effect, all trees in and around the campsite are assumed to have a 100% chance of striking the target area when they fall, thus the probability of impact is equal to the proportion of time that the campsite is occupied.

Visitation in many parks is season, thus the percent of occupancy (impact) will be based on seasonal visitor use, rather than annual. Occupancy is calculated differently for day use versus overnight use.

Overnight use (family unit campgrounds and group campgrounds): the average annual occupancy for family camp units, expressed as a decimal, is a function of the sum of campsites occupied each night during peak season divided by the total number of campsites available during that same period of record.

For new public use areas (or other areas without occupancy figures), which do not have attendance figures, compiled, occupancy should assign a .20 value for overnight sites in more seasonal areas and a .25 value for year round use areas.

Day Use:

Day use of Department facilities and wildlands are highly variable. It can be in the form of destination visitation (i.e. a day trip to historic sites) or visitors can use it as a rest stop while traveling. Day use can also vary in intensity. Use patterns can be highly focused (i.e. visitation to a small cultural and historic park) or use can be diffuse such as day hikes in a County Park. An even more diffuse pattern is horseback, bike, or motorized vehicle travel through the wildlands of a park unit. It may even be a combination of patterns such as a group picnic followed by dispersed individual activities.

The department maintains day us visitation records for most County Park Units (in the form of activity reports). These figures are estimates, and are not adjusted to reflect differing use patterns at each County Park Unit. Further, the data has no relationship to the campground occupancy data if such facilities exist within the particular County Park Unit. Day use occupancy is a function of the time spent by one person in any one spot times (x) the number of visitors to that spot, divided by (/) the total time available in a year. Day use, by definition, does not include nighttime use therefore even in the most accessible parks utilized by large number of visitors, the day use cannot exceed 50% annually.

The average annual day use attendance figures (appendix A) can be divided by the number of annual visitors to the County Park system to obtain the percent occupancy for all day use facilities within the County Park Unit. Diffused day use activities generate such a low occupancy level that the risk of injury or damage is considered insignificant and therefore such areas are not surveyed (consistent with the California State Park Tree Safety Program, the model and training standard of the County Park Program).

Fixed Property

The probability of impact for an immobile structure is equal to the portion of the total area which a failed tree or tree part can strike that is occupied by the structure. For example if a tree with no lean and a balanced crown has a defect at the trunk base or roots, it could potentially fail in a 360° arc. If the portion of the building within this target circle occupies a 90° arc than the Target Occupancy of the building is 25% for the subject tree. However if that subject tree had a lean toward the building such that it could potentially fail only within an 180° arc than the Target Occupancy of the building would be 50 %. Furthermore, if the subject tree had a severe lean toward the building such that it could potentially fail within a 120° arc then the Target Occupancy would be 75%.

Size of Failed Part

Roots or lower trunk failure

The larger the failed part and the greater the distance that the part has to fall, the greater the kinetic energy applied to the target area. Two failure positions on the tree are considered to assign a Size Value. If the most likely point of failure is at the roots or lower trunk then the whole tree is involved. For this situation, the size of the trunk is used to assign a Size Value. Size Values for whole trees (i.e., failure point at base of tree) are as follows:

0. Trees less than 6 inches in diameter at breast height (DBH) that fail at the roots or lower trunk generally do not cause injury or property damage. This situation is assigned a zero (0) value denoting that no action is necessary even if other categories are assigned higher values.

1. DBH ≥ 6 inches and < 10 inches.

2. DBH ≥ 10 inches & < 20 inches

3. DBH ≥ 20 inches

Crown or upper trunk failure

If the most likely point of failure is in the upper trunk or crown than the estimated weight of the failed tree part is used to assign a Size Value. This latter criterion takes into account the difference in weight of cured dead wood versus green live wood. It also accounts for fact that sound wood tend to disintegrate gradually after death; first leaves, followed by twigs, branch part, and finally main trunks, then. Large dead parts usually fail at points of structural weakness that existed prior to death, such as wounds. Size Values for tree parts in the upper trunk or crown are as follows:

0. Tree parts from the upper crown that weigh less than 10 pounds usually do not cause significant injury or property damage. This situation is assigned a zero (0) value denoting that no action is necessary even if other categories are assigned higher values.

1. Weight of failed tree part ≥ 10 pounds but < 25 pounds

2. Weight of failed tree part ≥ 25 pounds but < 100 pounds

3. Weight of failed tree part ≥ 100 pounds

Failure Potential

The potential of a tree or tree part to fail is a function of the tissue strength of the species, the amount and configuration of sound wood at the weakest point, and the bending and twisting forces applied to that weak location from gravity and wind. Weather is often the catalyst. For example, high winds can exploit the weakest point of the tree part. The part could fracture and immediately fail, or the tissue could have multiple micro-fractures may predispose the tree part to fail at a future date. Wind gusts when combined with saturated soil conditions can sometimes cause uprooting of otherwise healthy stable trees. This is only important if the target area is routinely occupied during the inclement weather periods.

Failure potential is given a numerical rating for several structural defect types including: general strength loss with and without wood rot, root loss, taper, and summer branch drop. Other structural defects such as narrow crotch attachments, lean, multiple branching, asymmetric crowns, offsets (or crooks) and sweeps have not been numerically rated. Failure potential values are segregated into weak wood species and strong wood species. Failure Potential values are assigned according to the worst defect on the subject tree. A tree with no defects or strength loss < 5 % is assigned a failure potential value of zero (0) denoting that no action is necessary even if other categories are assigned higher values.

If the tree is growing in the open or on the edge of an opening or has a significantly asymmetrical crown then the Failure Potential value derived from strength loss or taper should be increased by 1.

Strength Loss

The tested Modulus of Rupture for green wood is the parameter used to assess wood tissue strength (see Appendix B). For the purposes of this program, a strong wood species is defined by a green wood Modulus of Rupture > 7,000 P.S.I.

The configuration of wood is characterized as the deviation from a solid cylinder of wood. For uniformly hollow trees with no other defects in the sound wood the Wagner (1963) formula is used.

For hollow trees with cavities the Smiley and Fraedrich (1990) formula is used. This formula assumes no callus roll or woundwood as it is sometimes called. Callus rolls often form at the edges of the cavity opening and will have a compensating effect on strength loss by placing sound wood in a critical position. A large callus roll has similar attributes to reaction wood and may be a response of the tree to compensate for the loss of strength in that position. The callus roll is often stronger than regular wood sometimes significantly so (Kane & Ryan 2003). A complete callus roll is defined as one that has achieved more than a half circle in cross-section. If one complete callus roll is present, subtract 1% strength loss. If a complete callus roll is present on both sides of the canker, subtract 2% strength loss.

Failure Potential values for strength loss are as follows:

0. Strength loss < 5 %

1. 5 – 25 % strength loss for weak wood species
   5 - 30 % strength loss for strong wood species

2. 25 - 33% strength loss for weak wood species
   30 - 40% strength loss for strong wood species

3. ≥ 33 % strength loss for weak wood species
   ≥ 40 % strength loss for strong wood species

Root Loss

Failure Potential values for root loss are the same as for strength loss, and the strength loss thresholds for weak and strong wood shall be applied. The structural root zone shall be examined for the presence of live permanent roots capable of providing support to the tree. A live but rotten root must have a thickness of sound wood ≥ 15% of the dbh to be considered viable. If the tree lacks a full complement of structural roots (i.e., < 360° arc) the % of the structural root zone that lacks viable support roots shall be estimated.

Red Ring Rot (Phellinus pini).

Phellinus pini produces a different pattern of wood rot creating alternating rings of rotten versus sound wood. In timber cruising, a single *P.pini* conk or conk cluster results in culling the wood for a distance of 10 feet above and below the location of the conk (cluster). A healthy vigorously growing tree will add new sound wood to its diameter faster than the *P. pini* decay can degrade the wood strength. The reverse is true when the trees vigor declines significantly.

1. Disease present: one *Phellinus pini* conk or conk cluster present

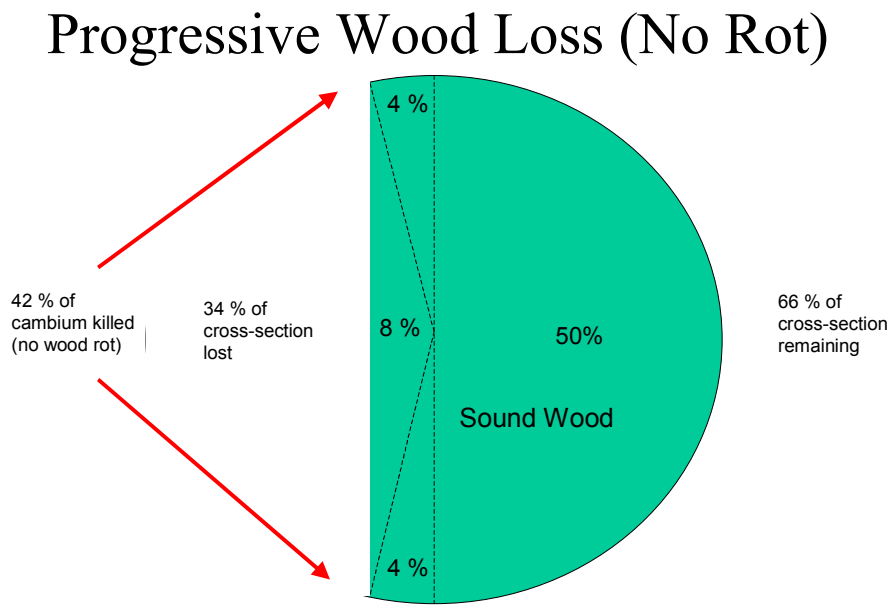
2. Disease significant:

   Weak Wood: ≥2 conks (conk clusters) separated by ≥ 10 feet on the trunk.
   Strong wood ≥ 3 conks (conk clusters) separated by ≥ 10 feet on the trunk.

3. Disease significant AND Tree vigor poor.

Canker with NO wood rot present

The rust progressively spreads tangentially killing cambium and thus preventing diameter growth along 1 face of the trunk. As infection progresses and the rest of the trunk continues to grow, the trunk begins to resemble a kinked pipe.



For this wood loss pattern a linear relationship between the loss of cross-sectional area and strength loss is assumed. The following table identifies the % loss of cross-sectional area in the trunk as a canker disease (no rot) progresses around the circumference.

Cambium Kill (% of Circumference)	Cross-sectional Area Lost
42 %	34 %
44 %	38 %
46 %	42 %
48 %	46 %
50 %	50 %

Failure Potential Value is assigned according to strength loss (i.e., loss of cross-sectional wood). Callus rolls or woundwood as it is sometimes called, often form at the edges of the infection. A large callus roll has similar attributes to reaction wood and may be a response of the tree to compensate for the loss of strength in that position. The callus roll is often stronger than regular wood sometimes significantly so. A complete callus roll is defined as one that has achieved more than a half circle in cross-section. If one complete callus roll is present, subtract 1% strength loss. If a complete callus roll is present on both sides of the canker, subtract 2% strength loss.

Taper

Taper is the relationship of the length of a trunk or limb to its diameter. During each growing season a tree limb/trunk will elongate first and if resources are available will then add wood to its circumference. If the trunk or limb is repeatedly unable to balance its diameter growth with its length, the wood will be unable to support the spindly stem from the forces of gravity and wind. Lack of light to carry out Photosynthesis limits the trees ability to add diameter growth. The taper of the tree trunk may be critical if a subordinate or suppressed tree has grown in a dense forest where sunlight is limited. Taper may also be problematic for trees where significantly more resources are allocated to length growth than are devoted to diameter growth. For example: 1) trunks sprouts from large stumps; 2) suckering limbs connected with large root systems and 3) poor pruning practices such as lions tailing can inhibit diameter growth in the lower portion of the stem.

$$\text{Taper ratio} = \frac{\text{Stem Length}}{\text{Stem Diameter (excluding bark)}}$$

A trunk taper ratio of 100 to 1 has a very high probability of failure (Oliver & Larson 1996). Failure Potential Values are assigned as follows:

1. Taper ratio < 75 to 1

2. Taper ratio > 75 to 1.

3. Taper ratio > 90 to 1.

Summer Branch Drop

Summer Branch Drop (SBD) is a weather dependent phenomenon: a sound subordinate branch can explode off a tree on a hot windless day, the break point often along the subordinate branch away from the point of attachment with the dominate limb or trunk. There are no exterior symptoms of this phenomenon. Indeed, existing breaks cannot be distinguished from those caused by the wind. One indicator is that a particular species tends to exhibit this type of failure. However, the only clue is whether the tree has exhibited this type of failure before. A Failure Potential Value is assigned as follows:

1. Species is prone to SBD.

2. SBD is suspected on the subject tree (existing breaks fit the SBD pattern).

3. SBD has been documented on the subject tree.

Emergency

A failure in progress is: 1) a broken but still attached branch, 2) a partially uprooted tree, or 3) a split fork. This condition is assigned a unique value of 9 in order to give the tree an emergency action threshold if the values of the other three categories are at least 1.

ACTION THRESHOLDS

No action is defined as a situation where the probability of injury or damage is very low. A zero value in any of the 4 categories usurps all other category values and indicates that risk mitigation is unnecessary.

Optional is defined as a non-urgent situation where the probability of injury or damage is in direct proportion to the risk score. Trees may be mitigated in order of highest risk score.

Priority is defined as a situation where failure/ injury/damage is likely before the next inspection cycle. This is not considered an emergency. It assumes a reasonable length of time to mitigate hazard (e.g., 1 month for work by park staff, 3 months for contract work).

Emergency is defined as a failure resulting in injury and/or damage could occur in less time than the time to mitigate. Site must be closed until after mitigation.

TABLE. Risk Rating Action Thresholds

THRESHOLDS	TARGET	OCCUPANCY	SIZE OF TREE PART		FAILURE POTENTIAL
Category Values are added			Root / Trunk Base Failure	Limb/Top Failure	
NO ACTION **Any Category = 0**	**0** Property only Damage value ≤ mitigation cost	**0** ≤ 1%	**0** dbh < 6”	**0** < 10 pounds	**0** No defects Strength loss < 5 %
OPTIONAL **Score = 4 - 10**	**1** Property only Damage value > Mitigation cost	**1** > 1% & < 25 %	**1** dbh = 6 – 10”	**1** 10-50 pounds	**1** Weak wood 5-25 % strength loss Strong wood 5-30 % strength loss Taper ratio < 75 to 1 Ring rot present Species prone to SBD
PRIORITY **Score = 11**	2 Property only (incl. animals) Damage value very high	**2** 25 - 50 %	**2** dbh = 11-20”	**2** 50-100 pounds	**2** Weak wood 25-33 % strength loss Strong wood 30-40 % strength loss Taper ratio > 75 to 1 Ring rot significant SBD suspected
EMERGENCY **Score ≥ 12**	**3** Human	**3** > 50 %	**3** dbh > 20”	**3** > 100 pounds	**3** Weak wood > 33 % strength loss Strong wood > 40 % strength loss Taper ratio > 90 to 1 Ring rot significant & low vigor SBD documented
					9 Failure in progress

Occupancy may be calculated on annual basis or for the critical time period (e.g., Summer for SBD, winter months for uprooting)
SBD = Summer Branch Drop: criteria apply only to branches.
MOR = Modulus of Rupture for Green wood. Strong Wood ≥ 7,000 P.S.I.
Strength Loss formula for: 1) hollow stems, 2) % cross-sectional area, or 3) structural root loss.

Taper Ratio = wood column length to wood column diameter (not including bark).

MITIGATION

One of the simplest methods of mitigating a high-risk situation involving a live tree is to move the target. While the probability of tree failure does not change, this action greatly reduces the probability of impact.

Tree Removals

If the target cannot be changed or relocated, the tree can be modified to lower the risk of failure. Tree removal is frequently the cheapest, especially if the tree can be felled whole, rather than in sections. However, trees contribute significantly to the overall aesthetics and character of the park setting and specific site, and the loss of these attributes may take decades to replace. Whole tree removal should be avoided especially as a viable management option when as area has an operational vegetation management plan that specifies desirable tree densities and procedures to reestablish trees.

Many other arboricultural measures are available which will reduce the risk, maintain the aesthetics and park character of the site, and extend the longevity or useful life of the tree. These include trimming, cable, rod, and support bracing.

Pruning

Tree pruning is an alternative generally reserved for tree species, which retain dormant buds along their twigs and major branches. Most conifers tend to elongate from buds formed during the previous growing season are not suited to partial crown removal; these species have no mechanism to reestablish foliage into the zones where foliage was removed.

There may be reasons for pruning trees. Short-term, pruning reduces the risk of failure by reducing the weight of the crown and reducing the wind resistance. Long-term, pruning can be used to improve the structural characteristics of the tree. First, rapid-elongating stems can be trimmed to slow growth and thus improve taper. Second, reducing the amount of foliage can be used to compensate for a loss of roots. Third, potentially weak branch attachments can be eliminated when the tree is young.

In older trees, significant crown reduction pruning on only one stem above the weak crotch can strengthen weak crotches with no imbedded bark. This will slow the diameter growth of that one fork, subordinating it to the other stem and thus stimulating a laminated growth pattern at the crotch, thereby improving its strength. Older trees with weak crotches that have imbedded bark, cracks, or splits, will have to undergo significant crown reduction on both forks and possibly cables and/or rod bracing for large forks or removal of one of the forks.

The department has adopted the pruning specifications of the western chapter of the international Society of Arboriculture. Pruning should not be conducted during the time bud break and initial

elongation of new shoots to minimize stress on trees. This physiological process varies among species and geographic areas. Since pruning wounds the tree, excessive pruning can severely hamper the tree's ability to recover. The following chart indicates the total amount of foliage to be removed from a tree per year.

AGE	**Old** 5 %	**Mature** 10 %	**Young** 15 %
VIGOR	**Poor** 5 %	**Average** 10 %	**Good** 15 %

Total % foliage removed = Age value + Vigor Value

Bracing

Cable bracing is a mechanical supplement designed to support tree parts for which the risk of failure cannot be significantly reduced through trimming alone. The goal in cabling multiple leaders is to restrict the movement between individual stems built not restrict the movement of the entire crown.

Rod bracing can be used to tightly bind a weak connection where two or more limbs join, to reconnect two or more stems that have partially split or it can be used to strengthen large partially rotted stems, which are likely to split.

Ground support bracing is a non-compressible, sometimes articulated, permanent scaffold, which restricts further lean of a tree or downward movement of a large branch. The support brace should be designed to allow horizontal movement of the supported limb. A rigid brace will change the fulcrum of branch movement form the limb-trunk attachment to the connection point of the support brace with the supported limb.

Trees with an induced lean can be frequently stabilized. In forested areas, especially riparian, uprooted trees are a natural and frequent occurrence and many hardwood species will continue to grow in a prostrate condition. This especially important with hardwoods in the hot, dry conditions where shade trees are at a premium for visitor safety and park aesthetics.

- Uprooted trees that continue to live should not be removed if they can be made relatively free of danger to people or property.
- Smaller trees with severe leans or partial uprooting can usually be pulled to an upright position and braced temporarily until the tree settles and new rots are established.
- If a leaning tree cannot be brought to an upright position, it may be possible to stabilize the tree in its leaning posture by placing support braces at one or more points beneath the bole or under the main limbs.

All bracing support structures should be attached only after pruning has been completed. Bracing is an expensive option for risk mitigation, thus the cost must be evaluated in terms of the benefits. Bracing is only appropriate for trees that are both valuable and healthy. Trees can be valuable in an historic sense or valuable in an aesthetic sense in that they are accessible by large number so f

visitors; and their loss represents a significant degradation of site aesthetics. Trees are considered healthy if they are expected to survive for at least 10 years after the proposed action.

The Department has adopted the bracing standards of the National Arborists Association.

Woody Debris Disposal

A considerable amount of woody debris can be created by tree removal and pruning operations. The most ecologically sound method of disposal is to cycle this biomass to the site from which it was created. However, large volumes of this material should not be left on the site in the unmodified condition of logs and branches due to insect pests, fire hazard, and visitor liability.

Sound logs and large limbs can be bucked up and split for firewood, preferably within 1 week of creation so that the cambial wood dries and will not support bark beetle offspring. Large logs can be laid on the soil surface for vehicle bumpers only if their presence will not dramatically increase the bark beetle population or ground squirrel population.

Some costs may be recovered if marketable portions of the wood are given to the contractor. Indeed, other services, such as stump grinding or chipping may be subsidized if the value of the wood exceeds the removal costs.

A portable chipper is the most effective means of modifying small woody material. Wood chips can be disbursed over the exposed areas of soil in the primary use areas of the campsites (i.e., area between the picnic table, stove and parking spur). This will reduce erosion and reverse soil compaction problems by stimulating break up via soil fauna.

Stumps of non-sprouting trees and undesirable sprouting trees should be ground to below soil level and covered with litter/duff wherever possible.

Tree Planting

All visitor use areas incur a significant amount of “wear and tear” form normal use. The effects on the vegetation and animals are cumulative. Restoration of facilities areas should be identified in an approved vegetation management plan, but specific critical needs may be mitigated on a case-by-case basis.

Tree replacement in harsh sites is a critical need in many of the park units. One alternative, which may be effective for less harsh sites, is to promote natural regeneration via site preparation, site closure, and seedling surveys. For harsh sites such as low precipitation zones, which have less intense visitor use, the only alternative may be off-site seedling propagation and transplanting. With either alternative the desired seedlings must be protected from competition, animal damage and trampling.

The Parks Natural Resource Management Program should establish long-term agreement with local nurseries to propagate and maintain native seedlings for planting into developed areas of the Park system. This could also be accomplished through the use of a park unit greenhouse and volunteers

collecting, propagating, a maintaining and transplanting seedlings. Once transplanted all seedlings must be maintained throughout the establishment period form competition, animal damage and visitor impacts.

Construction Activities

Trenching for utility lines can be particularly destructive to tree roots. Tree root damage only affects the tree's stability in the short-term if the structural roots are severed. Most of the structural roots can be found in the zone around the base of the tree. The best estimate for the size of this zone is derived from tree transplanting guidelines; the structural roots are located adjacent to the trunk within the circle of radius equals to 5 times the diameter of the trunk measured at breast height (4.5 feet above mean ground level). Trenching should avoid this zone if at all possible.

Any utility line traversing this zone should be established by 1) tunneling underneath the roots at a depth of at least 3 feet, 2) hand removal of soil from around roots between 0 to 3 feet deep, or 3) by hydraulically removing the soil from along the roots 0 to 3 feet deep.

A trees ability to recover from root loss depends on it's ability to re-establish roots. The standard construction method for replacing soil trenches uses mechanical compactors applied to sequential layers of fill each 6 to 8 inches deep. This creates a medium that can be unsuitable for new root growth; dry and dense, sometimes denser than the native soil. A better alternative for settling fill soil outside the road and trail beds is to soak each layer of fill with water. This produces a wet less dense medium, which will attract root growth.

Appendix B Wood Strength

SPECIES	Modulus of Rupture (Green wood)
Alder, red (*Alnus rubra*)	6,500
Ash, Oregon (*Fraxinus oregona*)	7,600
Ash, white [A])	9,500
Aspen (*Populus tremuloides*)	5,100
Basswood (*Tilia americana*)	5,000
Cedar, Incense (*Calocedrus decurrens*) & Port-Orford (*C. lawsoniana*)	6,200
Cedar, Western red (*Thuja plicata*)	5,100
Cottonwood, black (*Populus trichocarpa*)	4,800
Cottonwood, eastern (*Populus deltoides*)	5,300
Douglas-fir (coast) (*Pseudotsuga menziesii*)	7,700
Elm, American (*Ulmus Americana*)	7,200
Fir, White (average of *Abies concolor* & *A. grandis*)	5,800
Fir, red (*Abies magnifica*)	6,000
Sweetgum (*Liquidambar styriciflua*)	7,100
Hackberry (*Celtis occidentalis*)	6,500
Hemlock, western (*Tsuga heterophylla*)	6,600
Larch, western (*Larix occidentalis*)	7,700
Locust, black (*Robinia pseudoacacia*)	13,800
Madrone, Pacific (*Arbutus menziesii*)	7,600
Magnolia, southern (*Magnolia grandiflora*)	6,800
Maple, bigleaf (*Acer macrophyllum*)	7,400
Maple, silver (*Acer saccharinum*)	5,800
Maple, sugar (*Acer*)	9,400
Oak, California black (*Quercus kelloggii*)	6,200
Oak, Oregon white (*Quercus garryana*)	7,700
Oak, red (average [B])	8,500
Oak, white (average [C])	8,100
Pine, lodgepole (*Pinus contorta* var *murrayana*)	5,500
Pine, ponderosa (*Pinus ponderosa*)	5,100
Pine, sugar (*Pinus lambertiana*)	5,100
Pine, western white (*Pinus monticola*)	5,200
Redwood, Coast (*Sequoia sempervirens*)	7,500
Spruce Sitka (*Picea sitchensis*)	5,700
Sycamore, American (*Platanus occidentalis*)	6,500
Tanoak (*Lithocarpus densiflorus*)	10,700
Walnut, eastern black (*Juglans nigra*)	9,500
Yellow-poplar (*Liriodendron tulipifera*)	5,400

A. Average of (*F. quadrangulata, F. pennsylvanica, and F. Americana*)
B. Average of *Q. velutina, Q. laurifolia, Q. palustris, Q. borealis, Q. coccinea, Q. falcate, Q. falcate* var. *pagodaefolia, Q. nigra,* and *Q. phellos.*
C. Average of *Q. macrocarpa, Q. prinus, Q. stellata, Q. michauxii, Q. Bicolor,* and *Q. Alba.*

Modulus of Rupture measured in Pounds per Square Inch

From handbook, US Dept. of Agriculture. Handbook 72 & from unpublished testing

Appendix C. Beaufort Scale of Wind Velocity

Beaufort number	Wind Velocity MPH	Terms	Description of effects
0	<1	Calm	Smoke rises vertically; no movement of leaves, brushes, trees or grass
1	1-3	Very light	Direction of wind shown by smoke drift; tall grass and weeds sway slightly; quaking aspen leaves move; small branches move slightly; small branches move gently; dead leaves on oaks rustle.
2	4-7	Light	Wind felt on face; trees of pole size in open sway gently; small branches of pine move noticeably; dear, dry leaves rustle and move; strands of broom sway.
3	8-12	Gentle	Leaves and small twigs in motion; dry leaves on ground move about; twigs of hardwood trees move distinctly, and large branches of pine in the open toss; whole trees in dense stands sway; trees of pole size in the open sway noticeably.
4	13-18	Moderate	Small branches move; tops of large hardwood trees sway noticeably; pines of pole size in the open sway violently; whole trees in dense stands sway noticeably.
5	19-24	Fresh	Inconvenience is felt in walking against wind; branchlets are broken from tree; small trees in leaf sway; entire hardwood trees sway; their tips whip about violently; twigs broken from pines.
6	25-38	Strong	Progress is impeded when walking against the wind; large branches in motion; branches broken from hardwood trees and tops in conifers.