How to Detect and Assess Hazardous Defects in Trees

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Defects and their risk of failure

There are as many ways for trees to fail as there are trees. An ice storm can overload all the branches on a tree, a blustery wind can blow down a tree if its roots are restricted or a cracked tree can fail just under its own weight. See Figures 3.1, 3.2, and 3.3.

Figure 3.1. *Branch union failure during an ice storm.*

Trees are designed to easily withstand the normal windstorms and winter storms that occur, yet we have all seen trees that have failed. Trees fail when the load (weight and motion of the crown) exceeds the mechanical strength of their branches, stems or root systems. See Figure 3.4. This is true for both sound and defective trees, but defective trees can only withstand a fraction of the load that sound trees can withstand. Defective trees fail sooner than sound trees.

Figure 3.2. *Blowdown tree due to restricted roots.*

A sound tree becomes potentially dangerous when the tree's woody structure is weakened by one or more defects. Most defects can be linked to past wounding and decay, pest infestations, severe storms, or to growing conditions that limited the root system. Since defects, the old injury sites and nearby wood, are structurally weaker than uninjured wood, the tree is predisposed to fail at the location of the defects (Figure 3.5). During storms, pre-existing defects predispose trees to failure (Johnson and Johnson 1999).

Figure 3.3. *A cracked tree failed just under its own weight.*

Defects are visible signs that a tree has the potential to fail (Figure 3.6) and the location of a defect signals where failure is most likely to occur. Tree failure can be predicted because defects show us where the tree is likely to fail. This manual identifies seven categories of defects: decayed wood, cracks, root problems, weak branch unions, cankers, poor tree architecture, and dead trees, tops, or branches. See Box 1. Seven categories of defects. Examples of tree defects and risk rating systems were chosen to depict tree species and conditions that occur in the Northeastern U.S.

Figure 3.4. *Trees fail when the load exceeds the tree's mechanical strength.*

BOX 1

Seven categories of defects

- Decayed wood
- Cracks
- Root problems
- Weak branch unions
- Cankers
- Poor tree architecture
- Dead trees, tops, or branches

Figure 3.5. *Defective trees fail sooner than sound trees.*

Healthy, well-maintained trees that are growing on suitable sites will be able to minimize the impact of wounding and the extent of decay and other defects. Trees that are site-stressed have reduced energy reserves, and therefore, have compromised ability to deal with wounds and the ensuing decay. Urban trees are more likely to be site-stressed due to a number of factors. Most urban trees survive on construction-altered soils that may be compacted, poorly drained, high in clay, sand, or gravel, very alkaline or littered with construction debris. Quite often, these trees are growing in root-confined spaces,

Figure 3.6. *Defects are visible signs that a tree has the potential to fail.*

Figure 3.7. *When the roots, stem, or branches are defective, a tree can become hazardous.*

such as, narrow boulevards or sidewalk planting pits. See Figure 3.7. Additionally, many urban trees are subjected to chemicals such as deicing salts, herbicides and fertilizers commonly used in landscape maintenance. Poor tree maintenance exacerbates the stresses placed on trees by the above factors. These cumulative stresses all take a toll on tree vitality and structural integrity, increasing the risk of failure for urban trees.

In this chapter, seven common defects are presented along with inspection techniques to assess the risk of failure for trees with these defects. Each type of defect has a distinctive range of symptoms that indicates its severity and the tree's potential to fail. Three risk-of-failure ratings are used: low, moderate and high (See Form 3.1: Defective trees: Risk assessment guidelines). A tree with a low risk-of-failure rating has a defect that does not appear to be currently affecting the structural integrity of the tree. A tree with a moderate risk-of-failure rating may or may not result in eventual failure, but does not warrant immediate corrective action. A tree with a high risk-of-failure rating is in imminent danger of failing or has already partially failed. Corrective action should be taken as soon as possible.

Use the severity levels found in this chapter as guidelines when assessing trees. Remember, these are guidelines; no absolute rules can be made to cover the natural variability of trees and their defects. Although the list of defects and their combinations appears to be lengthy, it is not exhaustive. Inspectors need to use their judgment and local experience when evaluating and assessing tree defects.

Individual tree inspections are enhanced if inspectors have an understanding of the factors that create or accelerate the development of defects in trees. Several species have growth characteristics that make them prone to certain defects (Table 3.1).

Form 3.1. *Defective trees: Risk assessment guidelines (See Forms Section for a full-size copy of the form).*

Defective trees: Risk assessment guidelines

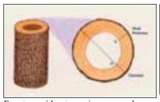
Tree defects	Moderate risk of failure	High risk of failure
Decay = Wood that has rotted or is missing. Indicators of advanced decay are rotten wood, fungal fruiting bodies, cavities, holes, open cracks or bulges in the wood.	• Indicators of advanced decay are found on 25% to 40% of the circumference of any stem, branch or root collar. • Shell thickness is >1 and < 2 inches of sound wood for each 6 inches of stem diameter and stem has opening < 30% of stem circumference.	• Indicators of advanced decay are found on ≥ 40% of the circumference of any stem, branch or root collar. *Note: In order to verify the extent of decay, you may want to use probes or drills to determine shell thickness.* • Stem has advanced decay and the shell thickness meets the following criteria: • Shell thickness < 1 inch of sound wood for each 6 inches of stem diameter, or, • Stem has an opening ≥ 30% of the stem circumference and shell thickness is ≤ 2 inches of sound wood for each 6 inches of stem diameter. • Any large branch with decay.
Crack = crack is a separation of the wood ; a split through the bark into the wood.	• Stem has a single crack and decay.	• Stem is split in two by a crack. • Stem segment has multiple cracks and decay. • Branch has a crack.
Root problems = inadequate anchoring by the root system, damaged roots or stem girdling roots.	• Roots within the area defined by the Critical Root Radius are ≤ 40% damaged, decayed, severed, or dead.	• Leaning tree with recent evidence of root lifting, soil movement or soil mounding. • Roots within the Critical Root Radius are ≥ 40% damaged, decayed, severed, or dead. • Girdling roots constrict ≥ 40% of the root collar.
Weak branch union = An epicormic branch or a branch union with included bark.	• Branch union has included bark.	• Weak union is also cracked, cankered or decayed. • Large epicormic branch on decaying stem.
Canker = An area where bark and cambium are dead.	• Canker or canker plus decay affect 25% to 40% of the tree's circumference.	• Canker affects ≥ 40% of the tree's circumference. • Canker plus decay affect ≥ 40% of the tree's circumference.
Poor architecture = growth pattern indicates structural imbalance or weakness in the branch, stem or tree.	• Branch has a sharp bend or twist. • Large, horizontal branch with several vertical branches on it.	• Tree with excessive lean (> 40°). • Leaning tree has a crack in stem. • Leaning tree has canker or decay on the lower stem. • Leaning tree has a horizontal crack on the upper side of the lean and/ or buckling bark and wood on the lower side.
Dead wood = A dead tree or dead branches.		• Any lodged branch. • Any dead tree, tree top or branch.

Defects : Defects are visible signs that a tree is failing or has the potential to fail. Defects predispose a tree to fail at the location of the defects.
Defective tree : A tree with one or more defects.
Risk of failure : Risk of tree or branch failure can be predicted because defects indicate which part of the tree is structurally the weakest. Since defect severity can change, the tree's risk of failure can change over time.
Moderate risk of failure : Currently, the tree's defects do not meet the threshold for failure. The defects may or may not result in eventual tree failure. "Moderate risk" trees need to be closely monitored to determine if the defects have changed since the last inspection.
High risk of failure : Currently, these defects indicate that the tree is in imminent danger of failing or has already partially failed. Corrective action should be taken as soon as possible.
Risk management : These guidelines are intended to provide the information needed to evaluate the failure potential of inspected trees. They are only guidelines. Absolute rules can not be made because of the natural variability of trees and their defects. ***All of the defective trees can not be detected, corrected or eliminated.*** However, by doing inspections and acting on them, we can successfully manage the risk of tree failure.

Inspections : Be systematic and complete. Inspect annually, except where policy indicates otherwise. Additional inspections should be done after severe storm events. Common sense, experience and professional judgment are required of the trained tree inspector.
Tree species, age, size and condition : These all play a role in the type, extent and severity of defects. Certain species are consistently prone to certain defects. Old trees tend to have more defects. Trees in good condition have the capacity to create more wood which can reduce the severity of some defects over a period of years.
Exposure and crown size : Open-grown trees with full crowns have a higher exposure to winds than trees growing in groups or stands. Recent change in wind exposure or crown size can affect the severity of defects.
Documentation : ALWAYS document inspections and actions. Use a form that records inspection date, tree species, tree location, defects and their severity, recommended actions, action taken and date. It's helpful to map the area. Remember to document the "Low Risk" trees.
Treatment : Correcting defective trees can be as creative as your imagination and resources allow. Treatments include: moving the target, rerouting traffic, closing off or fencing off the site, pruning the defective branches, reducing the crown weight/ exposure and, ultimately, removing the tree.

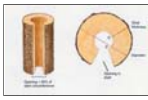
Epicormic branch : Epicormic branches are new, younger branches that replaced injured, pruned or declining branches. They form weak unions because they are not attached all the way to the center of the stem.
Decay : Decay is generally limited to the column of wood present at the time of wounding. Measure shell thickness to determine if enough sound wood remains to support the tree. The risk of failure increases when decay columns expand into the new wood because there is no sound shell of wood near those defects. Continuously expanding columns of decay are the result of inrolled cracks (rams-horning), girdling roots and canker-rot infections.

Minimum amount of sound wood in shell needed:



Need 1" of sound shell for each 6" of diameter	
Stem Diameter	Shell thickness
6"	1"
12	2
18	3
24	4

For stem without openings or cracks.



Need 2" of sound shell for each 6" of diameter	
Stem Diameter	Shell thickness
6"	2"
12	4
16	6
24	8

For stem with openings < 30% of stem circumference.

Critical root radius : The CRR is used to define the portion of the root system nearest the stem that is critical for stability and vitality of the tree. This area is usually <u>beyond</u> the dripline of the tree. The radius of this circular area is defined as

CRR (in feet) = DBH x 1.5.

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Table 3.1. *Tree defects by species.*

Species group	Commonly found defects	Comments
Ash	Weak branch unions Poor architecture Branch breakage	Due to included bark and opposite branching pattern Multiple codominant stems Branch shedding in trees > 15" d.b.h.
Aspen	Decay Canker Root problems	Common in older stems due to canker-rot fungus. Stem breakage at canker. Stem girdling roots.
Basswood	Decay Branch breakage	Common in older stems, usually large columns of decay. Branch shedding in trees > 15" d.b.h.
Birch	Decay Root problems Dead tree tops	Canker-rot common in stem. Susceptible to soil compaction, summer soil temperatures. Susceptible to boring insects if predisposed by root problems.
Black cherry	Branch breakage	Rapid decay of dead branches.
Boxelder	Decay Branch breakage	Wood is quickly and extensively decayed. Branch shedding in trees > 15" d.b.h.
Cottonwood	Root problems Branch breakage	Stem girdling roots Branch shedding in large, old trees.
Elm	Dead branches, tree Root problems	Due to Dutch elm disease. Stem girdling roots Included bark
Hackberry	Cracks Weak unions Branch breakage	Common in lower stem. Common due to growth habit of tree. Branch shedding in trees > 15" d.b.h.
Hawthorn	Weak unions	Common due to branching pattern.
Hickory	Branch breakage	Branch shedding in trees > 15" d.b.h.
Honey locust	Canker Root problems Branch breakage	Susceptible to insect and fungal cankers. Stem girdling roots Branch shedding in trees > 15" d.b.h.
Ironwood	Root problems	Shallow root system is easily damaged.
Maples, red & sugar	Cracks Cankers Weak unions Root problems	Wounds during tree's youth become cracks as trees age. Susceptible to insect and fungal cankers. Codominant stems commonly have included bark. Stem girdling roots.

Maples, silver	Same as maples, above Branch breakage	Wood tends to fracture. Branch shedding in trees> 15" D.B.H.
Oaks, red	Decay Dead branches Dead tree Branch breakage	Susceptible to brown-rot decay. Due to construction damage, borer attack or root decay. Susceptible to oak wilt disease. Branch shedding in trees> 15" DBH, esp. after stand thinning.
Pear	Weak unions	Multiple branching, included bark
Walnut	Branch breakage	Branch shedding in trees > 15" D.B.H.
Willow	Cracks Root problems Branch breakage	Wood is easily fractured. Stem girdling roots. Branch shedding in trees > 15" D.B.H.
All conifers	Decay Branch breakage	Susceptible to canker-rot decay fungus. Due to snow-loading or windstorms.
Balsam fir	Decay Dead top	Prone to stem and root collar decay. Susceptible to insects consuming needles or cambium layer.
Pines, jack & red	Dead top, dead tree	Susceptible to insects consuming needles or cambium layer. Jack pines susceptible to cankers.
Pines, white	Branch breakage Dead branches, tops	Wood in branches is easily fractured. Susceptible to white pine blister rust.
Spruces	Root problems	Shallow rooted and susceptible to windthrow.
Tamarack	Root problems	Susceptible to root rot.

All defective trees cannot be detected, corrected or eliminated

All defective trees cannot be detected, corrected or eliminated. To begin with, our knowledge of trees is less than complete. Although we can readily recognize most defects, there are root problems and some internal defects that are not easily discernable. These trees may require in-depth assessments and the use of specialized diagnostic tools. Secondly, defect severity can and does change with time. Inspection and correction schedules should be consistent from year to year. Finally, trees are masters at covering up problems and surviving. All defective trees cannot be detected; our aim is to find 80 percent or more of the defective trees with each inspection. By doing inspections and acting on them in a timely manner, we can successfully manage the risk of tree failure in our urban forests.