Minnesota DNR Forestry Oak Wilt Guide

Minnesota DNR Forest Health Program, April 2026

DEPARTMENT OF
NATURAL RESOURCES

Table of Contents

Introduction

This document provides detailed guidance from the DNR Forest Health Program on oak wilt management. It is primarily written for professional forest managers and rural landowners with ample technical knowledge of forest management.

Oak wilt is a deadly disease that affects all species of oaks found in Minnesota. It is caused by a nonnative, invasive fungus (*Bretziella fagacearum*, formerly *Ceratocystis fagacearum*). Oak wilt was confirmed in five Minnesota counties as early as 1944. Through 2025, we estimate oak wilt is present over the southern 48 percent of the red oak range in Minnesota, and it is slowly continuing to spread and invade unaffected forests.

While the oak wilt pathogen can infect all species of oak, those in the red oak group (hereafter referred to as red oaks) die in a single year, often dropping most of their leaves one to two months after infection. Trees in the white oak group die more slowly from oak wilt. Bur oaks (*Quercus macrocarpa*) die between one and seven years after infection, and white oaks (*Quercus alba*) die from one to more than 20 years after infection. Some white oaks can naturally recover from oak wilt. At this time, the relative susceptibility of swamp white oak (*Quercus bicolor*) in Minnesota is not well understood. Presumably, it is similar to that of white oak. Symptoms of oak wilt are shown in Appendix 1.

In forests with sandy soils, flat terrain, and where the majority of tree species are red or bur oaks, oak wilt commonly kills oaks in patches more than 1 acre in size. If oak wilt is left uncontrolled in a forest dominated by oaks, oak wilt will eventually kill oaks in gaps for other species to exploit. Maples and invasive buckthorns commonly colonize these openings.

Oak wilt spreads naturally in two ways: above ground by sap beetles that deposit pathogen spores on fresh wounds in the spring, and below ground through roots of individual trees that fuse together (called root grafts). Spore-carrying sap beetles typically fly less than 0.5 miles from an infected oak to a fresh wound. Wounds made in the spring are susceptible to infection for up to five days. Oaks usually graft roots with the same species, although different oak species will graft roots occasionally.

Humans can introduce oak wilt to new areas when moving wood from infected trees that died from oak wilt within the last 12 months. Firewood labeled as certified by Minnesota Department of Agriculture (MDA) cannot produce oak wilt spores and is legal to move throughout Minnesota.

Location of oak wilt in Minnesota

Minnesota DNR's Forest Health Program updates the map of oak wilt confirmations annually. We divide Minnesota into high- and low-risk zones. High-risk areas for oak wilt infection are within 20 miles of confirmed oak wilt (see Figure 1 on next page). Our data shows there is a significant risk of aboveground oak wilt infection if within 20 miles of confirmed oak wilt. This is due to unreported oak wilt and the difficulty of detecting oak wilt when it is not common. The high-risk area can shrink if isolated oak wilt infections are eradicated for five years, but this situation is rare.

Reporting and confirming oak wilt

Reporting oak wilt outside or near the edges of its current range is the crucial first step in stopping its spread.

If you see oak wilt symptoms (Appendix 1) outside or near the edges of the high-risk zone (Figure 1), report through the EDDMapS app, the GLEDN app, the EDDMapS website, to your local DNR forestry office, or by submitting actively wilting branch samples to the University of Minnesota Plant Disease Clinic.

If submitting or showing photos for diagnosis, include a photograph of the entire canopy in summer and a close-up showing freshly fallen leaves or wilting leaves on a branch.

For an accurate lab analysis, it is important to follow the clinic's sampling instructions. If branches are too high to reach, collect small wedges from trunks in autumn, and sample from at least two sides of the trunk. Keep samples cool, and ship for next-day delivery. It is best to ship samples earlier in the week to avoid samples sitting over the weekend. False negative sample results are not unusual, particularly from trunk samples and samples from infected bur and white oaks.

Confirm oak wilt with lab results prior to any control efforts. This is particularly important in situations involving suspected oak wilt in white oaks, when the person making the diagnosis is not highly experienced with identifying oak wilt, and when an expensive control solution is proposed.

Prevention

Preventing oak wilt is crucial to reducing its spread, especially in the high-risk zone (Figure 1). Above-ground oak wilt infection can generally be prevented by not wounding oaks from April through July when (1) oaks are most susceptible to infection, (2) the oak wilt pathogen is commonly producing spores, and (3) the two sap beetle species most responsible for carrying spores are abundant.

The highest risk period for above-ground oak wilt infection is in May and June. The average start to risk from 2009–2025 was April 17 in Rochester and April 27 in Aitkin. The beginning of this risky period varies greatly from year to year. As examples, the start of risk ranged in Brainerd from March 23–May 13 and in Rochester from March 18–May 7. Risk in March is unusual though. Even in Rochester, from 2009–2025, it only happened in 2012.

A rule of thumb is that risk for infection can start in later March or early April if daily highs reach 60°F for six consecutive days. The Oak Wilt Vectors Emergence Thermal Model is a tool to let you know if there is an infection risk for your particular area. It is particularly useful for loggers and arborists in April, allowing them to extend their productive work in many years while not exposing oaks to infection risk.

Though the start of above-ground infection risk varies substantially, there are no published observations that the end of infection risk varies. A theoretically small risk still exists after some point in July for the rest of the growing season; however, there have been no documented cases of oak wilt naturally developing from wounds made after mid-July in Minnesota, Wisconsin, or Michigan.

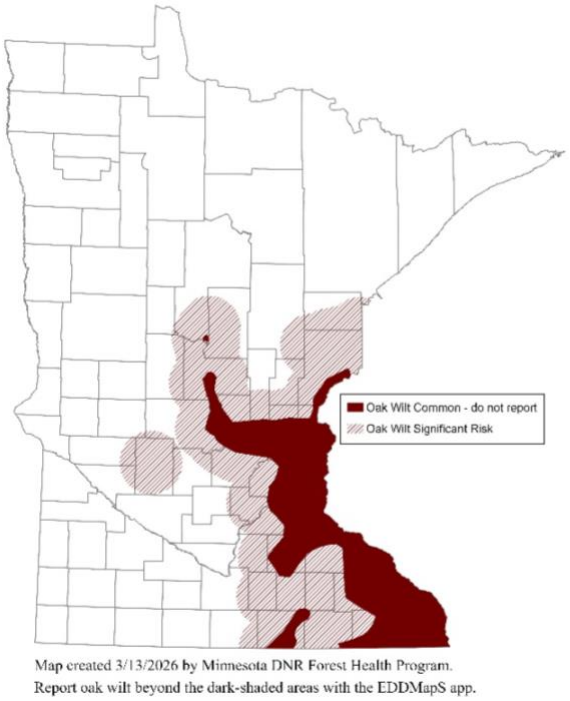

Figure 1. High-risk (hashed and red zones) and low-risk zones (white areas) for oak wilt infection in Minnesota as of 3/13/2026. Oak wilt is common in areas of solid maroon shading.

Prevention during forest management operations

If an oak stand is in the high-risk zone, and if the desired future condition is an oak or central hardwoods covertype, or a northern hardwood covertype with a significant component of northern red oak, avoid any activities that could wound living oak trees, including harvesting, cutting firebreaks, and working on trails and roads in or next to the stand from April 1–July 15.

> *DNR foresters: use the appropriate timber sale specification found in the Timber Sale Module to apply a seasonal harvesting restriction from April 1–July 15 unless with written permission.*

Avoid moving diseased oak wood April 1–July 15 to the edge of the oak wilt range or beyond. Process diseased logs shipped to mills before April 1. Ideally, mill managers would keep diseased logs separate to ensure they are properly handled before April 1. Wood chips, bark slabs, and debarked logs will not produce spores.

Exceptions to seasonal harvesting restrictions

There are reasonable exceptions for harvesting during the high-risk period in the high-risk zone. In all cases, the following risk reduction strategies are recommended*: (1) fell trees and move logs so oaks in adjacent forests are not damaged, (2) avoid leaving residual oaks within about 200 feet of the stand boundary if adjacent stands are oak forests, and (3) fell trees along the periphery of the stand away from adjacent stands' oaks. Following are examples of exceptions:

- Harvests in areas abundant to oak wilt and within oak stands heavily infected with oak wilt, dominated by a single species of oak, and on sandy soils. Harvesting in this situation accomplishes a salvage, pre-salvage, and regeneration harvest. It assumes that additional oak wilt infection won't significantly alter regeneration success since there is so much oak wilt already impacting the stand. It also assumes there is so much oak wilt in the surrounding area that infecting more oaks won't significantly increase oak wilt disease pressure to the surrounding landscape.
- Harvests in covertypes other than oak, central hardwood, or northern hardwood (with a significant component of northern red oak). In these situations, the following actions reduce risk further (these additional strategies are particularly important at the edge of the oak wilt range):
    - Retain a buffer of non-oak trees surrounding residual oaks to protect them from harvest damage.
    - Space residual oaks about 200 feet or more apart if not buffered by non-oaks.
    - Along the northern edge of the oak wilt range, monitor residual oaks between two and three months after harvest and control oak wilt if found.

**These strategies assume there is negligible risk to recruitment of oak seedlings and saplings. Meunier et al. (2019) showed that oak stump sprouting survival as well as oak seedling survival 10 years after harvest did not differ statistically between oak wilt pockets and healthy areas of forests.*

Prevention on recreational, construction, or residential sites

Prevent oak wilt by not pruning or damaging living oaks from April through July in yards or recreational settings (e.g., campgrounds). There is no risk or low risk to pruning outside of the high-risk zone in this timeframe, but a risk might still exist if there is undetected oak wilt nearby. If you must prune or accidentally wound an oak, immediately apply pruning paint, tree wound dressing, water-based paint, or shellac to the pruning cut or wound. This step effectively prevents oak wilt infection. Dead branches can be removed anytime during the year without risk of oak wilt infection, but caution should be taken not to cut into living tissue from April through July.

Avoid felling oaks from April through July in the high-risk area. If they must be cut down, apply paint immediately to the bark and to the last three annual growth rings of the stump to protect them and nearby oaks from oak wilt infection (Figure 2).

Figure 2. To prevent oak wilt, paint stumps, as seen above, immediately after cutting April through July (photograph from Wisconsin DNR).

If you plan to remove trees other than oaks from April through July in the high-risk zone, and if they are next to oaks, avoid damaging the adjacent oaks. Even a tiny wound can be infected.

Lot clearing operations, where oak stumps will be ground down or ripped out within weeks of cutting, are very low risk for oak wilt. The key is to avoid damaging oaks surrounding the site.

If oak trees or branches are a hazard to people, prioritize removing the hazard. Immediately paint fresh cuts to avoid oak wilt with a wound dressing paint or shellac.

Prevention with injections of propiconazole

Propiconazole (e.g., Alamo or Propizol) can be injected into healthy red oaks to suppress oak wilt symptom development for two years. It is a relatively expensive treatment and generally used on only a few high-value healthy oaks in yard settings.

Propiconazole does not prevent infections through root grafts, so injected oaks and those beyond injected oaks can still be infected through belowground spread. However, injecting valuable oaks with propiconazole every other year usually allows them to thrive, even when they become infected through root grafts. If a red oak in a yard gets oak wilt, and there are no barriers (e.g., driveways, roads, houses) between it and other red oaks, that would be an appropriate time to inject high-value healthy red oaks within about 75 feet of the diseased oak. For the year after wilt, consider injecting oaks up to 100 feet away. On sites where root grafting is common and red oaks are extremely valuable, due to some uncertainty with long-term effectiveness of propiconazole injection, we recommend root severing in addition to propiconazole injection (see control section below).

White oaks (*Quercus alba*) can be injected after they show initial symptoms of oak wilt (up to 50% crown wilt) and every other year thereafter to prevent the infection from spreading within the tree. Pruning out the dead branches is also advisable. These therapeutic treatments work on bur oaks (up to 30% crown wilt) but with a somewhat lower rate of success. Generally, there is less risk in preventatively protecting these white oaks versus therapeutically treating them (see above two paragraphs). *We highly recommend getting a lab confirmation of oak wilt on bur or white oaks before investing in therapeutic treatments.*

Injections are best done by professional arborists. Find a certified arborist by using the International Society of Arboriculture's Arborist Search. Alternatively, homeowners can treat their oaks themselves. Many companies sell injection equipment and fungicides, and online tutorials demonstrate how to inject oaks. Two types of injection techniques (sometimes referred to as infusions), macroinjection and microinjection, can be used to inject chemicals into trees. A recent small, unpublished research project in Minnesota showed no difference in effectiveness between these two techniques in suppressing oak wilt crown symptom development for two growing seasons (J. Juzwik, personal communication, February 2023). However, each one has benefits and drawbacks, and describing those is beyond the scope of this document. To learn more about injections, please see Oak Wilt Remediation by the Tier Tree Model, Part 2: Tree Injections, starting on page 34.

Controlling oak wilt

Controlling oak wilt usually involves two steps: (1) belowground control and (2) above-ground control. Cutting down dead or wilting oaks almost never stops oak wilt in forests where oaks are common, since cutting down oaks rarely kills their root systems where the pathogen resides the longest. To stop oak wilt from spreading to other oaks nearby, you must apply belowground control measures before cutting down wilting oaks.

Belowground control includes physically breaking root grafts between oaks or starving out the oak wilt pathogen in the roots by preemptively killing several healthy oaks surrounding diseased oaks. If severely wilting or recently killed oaks are cut down in spring, summer, or fall prior to belowground control, the oak wilt pathogen can be quickly sucked into the root system of adjacent oaks, spreading oak wilt more quickly than would occur naturally.

To control belowground spread of oak wilt, it is important to understand (1) the possible root grafting distance between oaks and (2) how long oak wilt has been underground spreading through roots. Oak wilt can survive in roots systems for about five years, slowly spreading to other oaks. Appendix 2 provides a table that estimates the distance in which oak wilt could move between oaks in one year. Root grafting abundance increases with increasing tree diameter, greater numbers of the same species of oak, sandier soils, shallower soils, and flatter terrain.

Above-ground control methods prevent spore production or block spore movement from diseased oaks. To control the above-ground spread of oak wilt, cut down red oaks that died after July 15 of that year only after belowground control has taken place. Diseased wood must be properly handled before the following April. White and bur oaks are rarely sources of spores, so we recommend not worrying about them for above-ground control. See How to properly handle infected wood for details.

Finally, avoid cutting down oaks when prohibited to protect endangered species, such as the northern long-eared bat. Tree removal within the 150-foot radius roost tree buffer zone for northern long-eared bat protection is *not* prohibited from August 1 through May 31 according to a Section 4(d) rule, described in the Lake States Forest Management Bat Habitat Conservation Plan. In cases where oaks cannot be cut down, herbicides can be sprayed onto girdles cut around their trunks to kill them, detailed on page 10.

Oak wilt control options

If done correctly, oak wilt can be successfully managed on a property-by-property basis throughout Minnesota, but control might not be appropriate in all circumstances. Consult the table on the next page to help you decide which oak wilt management strategy is most appropriate for your situation. Details on the strategies follow the table.

Cost-share for oak wilt control is sometimes available for woodland owners through programs administered by local USDA NRCS offices, county conservation districts, or DNR Forest Stewardship. DNR prioritizes oak wilt cost-share, if available, beyond the area where it is common.

Situation	*Recommended Control Options*
• Oak wilt confirmed in low-risk zone	Please report and see below for control
• Oak wilt not abundant • Threatened and endangered plants and buried cultural sites *not* present • Site relatively flat with soils that are at least 5 feet deep; no buried utility lines • Vibratory plows or trenchers available	Root severing with cutting to the line option (p. 10)
• The first two criteria in the above situation apply, but • shallow soils present, or • vibratory plows or trenchers not available, but bulldozers or excavators are	Stump extraction (p. 11)
• Oak wilt pocket and adjacent oaks well beyond grafting distance from other oaks	Host elimination (p. 11)
• Equipment such as vibratory plows or excavators not available, or • Cost is a limiting factor, or • Threatened and endangered plants or buried cultural sites are present. • Small oak wilt pocket (4 or fewer trees), and • Unstable trees are not a significant threat to people or buildings	Frill-girdle, herbicide (p. 12)
• The first four criteria in the above situation apply, but • Unstable trees are unacceptable.	Cut-stump, herbicide* (p. 12-13)
• Belowground control is not possible, but you want to do the bare minimum amount to lower oak wilt risk to your and your neighbors' properties.	Slowing above-ground movement (not a control strategy, p. 13)

• Oak wilt is significantly impacting a forest, and landowner
  ○ wishes to capture oak timber value, or
  ○ wishes to restore site to a more natural system
	Regeneration harvest (p. 13-14)

• Yard setting and cost not a limiting factor, or • Owner unwilling to sacrifice healthy oaks to ensure control effectiveness	Three alternatives to removing healthy oaks inside the barrier line (p. 11)

• Area already known to have oak wilt, and
  ○ A forest with oaks is not important to landowner, or
  ○ The forest has a diverse make-up of tree species or steep terrain, allowing for less efficient belowground oak wilt movement between oaks
	No control (p. 14)

**Considered an experimental control strategy, but observations indicate the method will provide some control.*

Always follow pesticide label directions. DNR foresters, follow the Division's Pesticide Use Guidelines.

Root severing with cutting to the line option

Minnesota-based research showed this method was about 84% effective for at least six years when a forester, experienced with oak wilt control, placed the barrier line and roots were severed to a 60-inch depth (Juzwik et al. 2010).

1. Between August 1 and when the ground freezes, sever root grafts around a buffer ring of healthy oaks that surround the diseased oaks (this sever line is called the primary barrier line or treatment boundary) (Figure 3). A vibratory plow is a good tool for this, since it disturbs the site the least, and some plows have 5 foot cutting blades. A 5-foot-deep barrier line has proven reasonably effective for control. Shallower root severing may not be worthwhile on sandy sites. Trenchers and excavators can also cut root grafts. Place the barrier line approximately halfway between oaks to the inside and outside of the line, placing it closer to the diseased zone if forced.

> **General guidance for placing the treatment boundary:**
> - See Appendix 2 for detailed guidance on placing the treatment boundary.
> - For new pockets (no oaks that died in prior years) on sandy soils, place treatment boundary 50 feet away from wilting oaks.
> - For older pockets:
>   - In hilly terrain or on loamy or clayey soils, include a buffer of one ring of healthy oaks adjacent to the wilting *and* dead oaks and stumps.
>   - On sandy soils on relatively flat terrain, include *at least* two rings of healthy oaks around wilting oaks *and* dead oaks and stumps.

2. [*option in rural forests where managers can't return to the site annually*] Next, remove healthy oaks, including saplings, within the barrier line (light-green trees in Figure 3), since they are likely to die from oak wilt in the next few years and can keep the pathogen alive longer. This removal is called "cutting to the line." For landowners and managers with time and resources, see Three alternatives to removing healthy oaks inside the barrier line.
3. Last, cut down diseased red oaks within the treated area and properly handle infected wood before April.
4. [*most aggressive control option*] Within a few hours after cutting down healthy oaks within the barrier line, apply herbicide to stumps and root collars according to label directions. Typically, the outer 2 inches of stump surface is sprayed with herbicide (Figure 6). Herbicides that could be applied to stumps include triclopyr (e.g., Garlon), imazapyr (e.g., Arsenal, Stalker), and glyphosate (e.g., Roundup Pro, Razor Pro). Herbicides applied to stumps may lessen the chances of roots re-grafting across the barrier line.

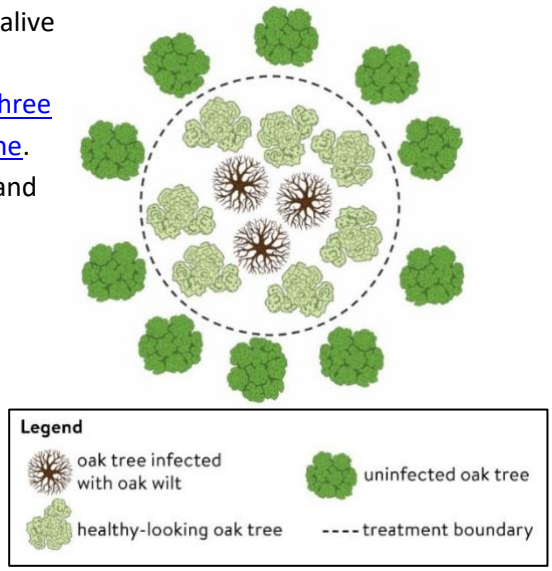

Figure 3. Barrier line or treatment boundary placement example for various oak wilt control methods.

Three alternatives to removing healthy oaks inside the barrier line

If you are unwilling to sacrifice healthy oaks inside the primary barrier line, you have three options:

A. Protect healthy oaks within the planned primary barrier line with propiconazole. This step should take place in summer prior to vibratory plowing or trenching. Propiconazole will not stop disease spread through roots, but it will keep oaks from developing wilt as long as they are injected every other year.
B. Install a secondary barrier line inside the primary barrier line (often this is placed around the dead or wilted oaks). This replaces steps two and four of root severing with cutting to the line option. Secondary barrier lines often fail, which creates additional control costs and complications, but could save many oaks between the primary and secondary barrier lines without having to use pesticides. Closely monitor healthy oaks between the primary and secondary barrier lines, and if you see them wilt, fell them in the dormant season and properly handle their wood.
C. Closely monitor healthy oaks within the primary barrier line, and if you see them wilt, fell them in the dormant season and properly handle their wood.

Figure 4. A vibratory plow severing roots, making a barrier line.

Stump extraction

Like the vibratory plow method, this method has a high success rate. It might be best incorporated into a regeneration harvest, since logging companies often have equipment capable of extracting stumps.

1. After August 1, cut down a buffer ring of healthy oaks around wilted and dead oaks (see treatment boundary discussion box on previous page to know how many healthy trees to cut down).
2. Extract stumps from the cut buffer trees before April, ensuring all roots are severed. This can be done with bulldozers or excavators. After stumps are removed, they are often put back in their holes.
3. Last, cut down diseased red oaks within the treated area and properly handle infected wood before April. Their stumps do not need to be removed.

Host elimination

To use this technique, wilting oaks and oaks around wilters need to be isolated from other oaks. Forest covertypes other than oak present opportunities to use this method. Diseased oaks and adjacent oaks should be at least 100 feet from the next nearest oak, although that could vary greatly depending on the size of oaks and terrain.

1. Simply cut down *all* heathy oaks after mid-July around the dead and diseased oaks.
2. Last, cut down diseased red oaks and properly handle infected wood before April.

Frill-girdle, herbicide method

This strategy can create hazardous trees, and girdling oaks with decay can be a very dangerous activity. Do not use it where people or structures could be hurt or damaged by failed girdled trees. Consider marking the area as hazardous with appropriate flagging or warnings. Recent research by Bronson et al. (2023) showed this method was about 80% effective over four years for oak wilt pockets of four or fewer trees and when setting the treatment boundary according to the first column in the table in Appendix 2.

Figure 5. Spraying herbicide into frill-girdles.

1. Mark oaks that wilted or are wilting after August 1. Then mark a buffer of healthy oaks around wilted and dead oaks (also, mark living oaks inside the pocket, down to 1 inch in diameter). This often includes two rings of the nearest healthy oaks around wilting *and* dead oaks but may include more. See Appendix 2 for a guide on buffer size.
2. Between August 1 and November 1, cut two horizontal, parallel girdles with a chainsaw or ax around each marked healthy buffer oak over 4 inches in diameter. Single girdles may be used successfully, but are not as effective. Girdles should be about 3 inches deep on larger oaks (they should cut into the sapwood about 1 inch), encircle the entire trunk, and meet end-to-end. Make the highest girdle about 24 inches above the ground, and separate the two girdles by roughly 6 inches. Clean wood chips out of girdles and apply herbicide to the girdles soon after girdling. Published and unpublished trials have had the highest success with the triclopyr-based herbicide Garlon (making a mixture with an oil carrier of 1 part triclopyr-based herbicide and 3 parts oil). Trials using the picloram and 2,4-D-based herbicide Tordon RTU were not successful in Michigan and Iowa. Oaks between 1 and 4 inches in diameter can be killed with a basal bark herbicide treatment instead of a frill girdle treatment. *Always follow pesticide label directions*.
3. Lastly, cut down diseased red oaks within the treated area and properly handle infected wood before April.
4. [optional] Cut down dead, girdled oaks before spring to eliminate hazard trees. Cutting down girdled oaks can be dangerous and ideally is done by an experienced tree feller.

Cut-stump, herbicide method

No research has been published on this technique, so it is considered experimental. The Minnesota DNR forest health team, Michigan DNR, and others are tracking some sites where this technique has recently been used. This method can be incorporated into forestry operations at little cost. Like the frill-girdle, herbicide technique, this method is likely to be successful on small oak wilt pockets when setting the treatment boundary according to the first column in the table in Appendix 2.

1. Optimally between August 1 and November 1, cut down a buffer of healthy oaks next to wilted and dead oaks. In most situations, we recommend determining the buffer boundary according to the first column in the table in Appendix 2. This buffer will normally include *at least* the two closest rings of oaks

around wilting *and* dead oaks. Be sure to cut all healthy oaks regardless of size, even small saplings within and around the oak wilt pocket. The larger the buffer, the larger the likelihood of success.

2. Immediately apply an appropriate herbicide to stumps. Typically, the outer 2 inches of stump surface is sprayed with the herbicide as well as the root flare (Figure 6). Examples of herbicides that may be applied to stumps: triclopyr (Garlon 4 Ultra, Garlon 3a, Remedy Ultra), imazapyr (Arsenal, Stalker), and glyphosate (Roundup Pro, Razor Pro). Always follow pesticide label directions.
3. Lastly, cut down diseased red oaks within the treated area and properly handle infected wood before April.

Figure 6. Kill stumps and root collars by applying herbicide to the outer 2 inches of stump surface, shown in blue, and the root collar (image from USDA Gen. Tech. Report NRS-96).

Slowing above-ground movement

To slow above-ground movement of oak wilt, cut down diseased red oaks in late autumn or winter after all trees have dropped their leaves for the fall. Properly handle infected wood before April. *This technique won't stop the underground spread of oak wilt in most situations.*

Regeneration harvest and forest restoration

If there are a few pockets of oak wilt that have been present for a few years in a forest, it is frequently not realistic to control the disease. In such cases, we recommend focusing on creating a healthier, more resilient forest for the future.

If the landowner wants to maintain a more mature forest, an option is planting and encouraging an array of native trees in canopy gaps (e.g., in areas where oak wilt has killed oaks), protecting saplings from deer browse, and ensuring that competing vegetation (e.g., common buckthorn, hazel, maples) is not shading desirable species. Young oak seedlings and saplings that grow from acorns or are planted rarely get oak wilt infection through roots, and they are an important part of the ecosystem. We recommend encouraging or planting multiple oak species in addition to other site-adapted trees.

If the landowner prioritizes timber production, harvesting most mature oaks while ensuring a younger forest regenerates afterward is a good approach. It is more beneficial to have an earlier harvest as oak wilt develops in a stand, to maximize oak regeneration from younger vigorous stumps and minimize invasive plants proliferating in oak wilt pockets. The oak wilt pathogen will die out in stumps and root systems

eventually, and oak wilt will likely not impede natural and artificial oak regeneration (Meunier et al. 2019). In a regeneration harvest:

- Maintain mature oaks for acorn production and other ecological reasons that are distant from oak wilt mortality centers. On sandy, flat sites dominated by a single species of red oak, we recommend keeping mature oaks that are about 200 feet or farther from known oak wilt centers.
- Maintain some mature trees other than oak for seed production and to promote tree species diversity.
- Consider planting different species of oak if they are not present on the site.
- Consider avoiding harvest from April through mid-July (see the Prevention during forestry operations section).
- Avoid spreading oak wilt.

No control

If the goals for a forest do not include having an abundance of healthy oaks, and if oak wilt is already established in the surrounding landscape, not controlling oak wilt may be appropriate. Likewise, in steep terrain and diverse forests, oak wilt's impact is often relatively small, making disease control unnecessary.

In forests where oaks are abundant, oak wilt will continue to spread from oak to oak, and new infections nearby could start as a result of above-ground spread. Invasive, undesirable vegetation or aggressive native shrubs and trees such as hazel, red maple, boxelder, elm, and cherry may take over in areas impacted by oak wilt.

Firewood timber sales

If firewood is being salvaged from dead or dying oaks from a forest known to have oak wilt, removal of oaks that have loose bark or no bark is safe. These oaks no longer can transmit oak wilt. Oaks with tightly attached bark that have been dead for more than one year are also safe to remove, but often, time of death is unknown, and in that case, removing oaks with tightly attached bark is riskier. Removal of infected oaks from a stand will not stop underground progression of oak wilt.

How to properly handle infected wood

Consult the table below to determine whether additional action is recommended to reduce the risk of spore production in the spring on infected oak trees, oak logs, or oak firewood:

Infected oak description	*Action needed to reduce spring spore risk*
Oak has been dead for more than one year	None (no risk)
White, bur, or swamp white oak	None (risk is very low)
Red oak* that wilted before July 15	None (risk is very low)
Red oak branches or trunks less than 6 inches in diameter	None (risk is low)
Red oak that wilted, but timing of wilt is unknown 1. Cambium is brown on opposite sides of trunk in summer or early autumn (Figure 7) 2. Cambium is white on at least one side of trunk	1. None (risk is low) 2. See options below (could produce spores in the spring)
Red oak wilted after July 15	See options below (could produce spores in the spring)

Figure 7. Blue arrows point to brown cambium in autumn.

** "Red oak" includes any oak with sharply pointed lobes on leaves: black, northern pin, and northern red oaks.*

If an oak log could produce spores in the spring:

- Avoid moving logs or firewood from April through July 15 within or beyond the area where oak wilt is common.
- Avoid moving logs or firewood from July 16 through March 31 outside the high-risk zone unless they will be processed or handled properly prior to April (see options below).

For diseased red oak logs larger than 6 inches in diameter and those that died after July 15:

1. Split into firewood segments no wider than 4 inches and pile loosely before January to allow logs to dry out before spring.
2. Burn, debark, or chip infected logs and branches before April. Chips and bark will not spread infection, so they can be left on site.
3. Kiln-dry or process logs into lumber before April.

4. Tarp diseased wood from April through July. Completely bury edges of the tarp to prevent sap beetles from coming into contact with spores. The tarp should be thick enough to prevent punctures.
5. For areas where oak wilt is common, leave infected trees standing for one year after death, beyond which they can no longer form spore mats. Infected trees add little risk to the general area if oak wilt is common. However, some communities have nuisance tree ordinances that prohibit leaving diseased oaks.

Appendix 1: Oak wilt photo guide

Initial wilt symptoms on a red oak. Leaves on outer branches are drab green, bronzed, or wilting.

Red oaks die one to two months after initial symptoms and drop most of their foliage. *Quick and abundant leaf drop in a matter of days after initial leaf symptoms distinguishes oak wilt from other killers such as twolined chestnut borer, Armillaria root disease, and herbicide.* Oaks struck by lightning can lose their leaves quickly but show a lightning scar. If oak wilt starts in early fall, the tree may appear to just be turning fall color. In that case, have a sample analyzed for disease confirmation.

Abundant green, brown, and bronzed leaves under an oak in the growing season signal oak wilt.

Oak wilt leaf symptoms on red oak (A), bur oak (B), and white oak (C).

Oak wilt on a large bur oak affected about 25 percent of its canopy in one summer. *Symptoms start in the outer canopy,* which distinguishes oak wilt from less concerning diseases such as anthracnose and bur oak blight.

Oak wilt kills neighboring oaks by spreading through connected root systems.


Brown or purple streaking on the wood surface is sometimes visible on actively wilting branches. Streaking must be visible on living branches immediately after bark removal and is more readily seen on white and bur oaks than on red oaks.

Elliptical pressure pads, formed in the center and on top of flat spore mats, are diagnostic for oak wilt and form on some diseased red oaks as they are dying or shortly after death. Opposing pads form between bark and wood, causing bark to crack (left). Pads and mats give off a fruity smell, similar to bananas or wine. Pads are light gray when fresh (middle) and quickly rot and turn black (right).

Oak wilt (left) compared to damage from twolined chestnut borer (right). Oak wilt kills red oaks in weeks and causes them to lose most of their leaves. It also can kill stump sprouts. Twolined chestnut borer usually kills oaks in two or more years, killing portions of the canopy each year, and does not kill small saplings. Leaves on oaks infested with twolined chestnut borer turn orange and brown and hang onto branches for weeks.

A bur oak suffering from oak wilt (left, in late June) and bur oak blight (right, in early September). Oak wilt kills leaves and branches starting from the outer part of the canopy. Bur oak blight kills leaves (but not branches) starting from the inner and lower part of the canopy.

Appendix 2: How to determine treatment boundary location to control oak wilt

For underground control of oak wilt, it is important to place the barrier line (or treatment boundary) at the right distance for successful control. This involves sacrificing healthy oaks (a buffer around wilted oaks) for the good of the entire forest. The larger the buffer, the more likely you'll succeed at stopping the spread of oak wilt.

The table below is an extrapolation from research conducted in Michigan. It suggests whether or not a healthy oak near an oak wilt pocket should be included within a treatment boundary. An illustration on how to use the table is in Lake States Woodlands: Oak Wilt Management—what are the options (Cummings Carlson et al. 2010).

To use this table, in an oak wilt pocket, add the diameter of a diseased oak to the diameter of a healthy oak to calculate their combined diameters at breast height (Combined DBH, left column). Looking at the four right-hand columns, choose the one that applies to your site and use the combined DBH row to see how far oak wilt could spread between the two oaks in one year, *in theory*. If the healthy oak is closer to the diseased oak than that distance, include it within the treatment boundary. Repeat this process for all diseased and dead oaks in the pocket and all healthy oaks around the pocket.

Example: a 13-inch-diameter red oak wilted on a sandy site, and it is next to three other dead oaks that wilted previously. You plan to stop oak wilt with a vibratory plow. You are wondering whether or not a 17-inch-diameter healthy red oak should be included within a vibratory plow line. This 17-inch oak is closest to the 13-inch oak in the disease pocket. First add those two diameters (30 inches of combined DBH). The distance in the table that matches this situation is 58 feet. If the 17-inch healthy oak is 59 feet, or more, away from the diseased oak, then the vibratory plow should go between it and the diseased oak. If it is 58 feet away or closer to the diseased oak, then the vibratory plow line should go around it to include it in the buffer.

We do not recommend using this table in steep terrain, in mixed species forests on heavier soils, or with white and bur oaks. In those cases, if using root severing techniques, place your primary barrier line outside one ring of healthy oaks located next to diseased oaks. For herbicide techniques, place the barrier line outside at least two rings of healthy oaks.

For root severing techniques, this table frequently overestimates the amount of oaks one needs to sacrifice to stop the belowground spread. However, unless you have ample experience or are employing one of the Three alternatives to removing healthy oaks inside the barrier line, we recommend using this table.

Table 1. Suggested buffer distance away from wilting or dead oaks (in feet).

Combined DBH (inches)	Any time the herbicide methods are used	Stump extraction, vibratory plowing, or trenching on sandy soils	Larger pocket on loamy sands, loams, or clays with stump extraction, vibratory plowing, or trenching	Smaller pockets (very few oaks killed in prior years) on loams or clays with stump extraction, vibratory plowing, or trenching
10	26	19	15	11
12	31	23	19	13
14	36	27	22	16
16	41	31	25	18
18	46	35	28	20
20	51	39	31	22
22	56	43	34	25
24	61*	47	37	27
26	66*	50	40	29
28	72*	54	43	31
30	77*	58	46	34
32	82*	62*	49	36
34	87*	66*	53	38
36	92*	70*	56	40
38	97*	74*	59	42
40	102*	78*	62*	45
42	107*	81*	65*	47
44	113*	85*	68*	49
46	118*	89*	71*	51
48	123*	93*	74*	54
50	128*	97*	77*	56
52	133*	101*	80*	58
54	138*	105*	83*	60
56	143*	109*	87*	60
58	148*	113*	90*	60
60	153*	116*	93*	60

Distances in gray that are marked with an asterisk (*) are farther than people have documented oak wilt moving underground in one year. For oak wilt pockets that are *less than one year old*, we do not recommend placing vibratory plow lines or extracting stumps more than 50 feet away from the outermost dead or dying oak (the maximum documented one year belowground spread of oak wilt observed on the Anoka Sand Plain was 25.2 feet (Shelstad et al. 1991)).

Since herbicide control techniques aim to starve girdled trees' or cut stumps' root systems, death of those root systems and subsequent death of the oak wilt pathogen take much longer than a year. For this reason, we include distances of underground oak wilt spread that would occur over multiple years.

Likewise, since oaks killed in prior years exist in most oak wilt pockets, often at the edges of pockets, the potential underground spread from those dead oaks is greater than the one-year spread potential.

This table was derived from research done in Michigan where the probability of underground disease spread within one year was modeled on deep sands and loamy sands in northern pin oak (*Quercus ellipsoidalis*) forests (Bruhn et al. 1991). The model was based on observations of northern pin oaks with maximum combined diameters of 44 inches and a maximum underground spread of oak wilt in one year of 41 feet. The authors of this research wrote that prior to their research, they observed a maximum annual spread of 60 feet in those forests. The first and second columns represent a 99 and 95 percent confidence interval, respectively, that oaks beyond the specified distance on deep sands avoid underground oak wilt infection for one year. The third column represents a 95 percent confidence interval on loamy sand, and the fourth represents an 80 percent confidence on loamy sand.

References

Bruhn, J.N., Pickens, J.B. and Stanfield, D.B. 1991. Probit analysis of oak wilt transmission through root grafts in red oak stands. Forest Science 37: 28–44.

Bronson, D.R., Meunier, J., Pearson, T.R., and Scanlon, K. Evaluating effectiveness of girdle-herbicide containment of below-ground spread of oak wilt (*Bretziella fagacearum*). Forest Ecology and Management 533.

Cummings Carlson, J., Martin, A.J., and Scanlon, K. 2010. Lake States Woodlands Oak wilt management—what are the options? University of Wisconsin-Extension G3590.

Juzwik, J., O'Brien, J., Evenson, C., Castillo, P., and Mahal, G. 2010. Controlling spread of the oak wilt pathogen (*Ceratocystis fagacearum*) in a Minnesota Urban Forest Park Reserve. Arboriculture and Urban Forestry 36(4): 171–178.

Juzwik, J., Schwingle, B., and Russell, M. 2016. Oak wilt in Minnesota. University of Minnesota Extension.

Meunier, J., Bronson, D.R., Scanlon, K., and Gray, R.H. 2019. Effects of oak wilt (*Bretziella fagacearum*) on post harvest Quercus regeneration. Forest Ecology and Management 432: 575–581.

Shelstad, D., Queen, L., French, D., and Fitzpatrick, D. 1991. Describing the spread of oak wilt using a geographic information system. Journal of Aboriculture 17(7): 192–199.

The forest health staff of the Minnesota DNR Division of Forestry thank the U.S. Forest Service and many DNR employees for reviewing these guidelines.