BALCONES CANYONLANDS PRESERVE
LAND MANAGEMENT PLAN

TIER II A
CHAPTER III
OAK WILT MANAGEMENT

March 2014

Balcones Canyonlands Conservation Plan (**BCCP**) and the
Balcones Canyonlands Preserve (**BCP**)

The **Balcones Canyonlands Conservation Plan** (**BCCP)** is a federal Endangered Species Act (ESA) incidental "take" permit for 30 years issued to Travis County and the City of Austin on May 2, 1996 by the US Fish and Wildlife Service (USFWS). Incidental take is the loss of federally listed species or their habitats in the course of (or "incidental to") otherwise legal actions, like development. Such permitting is authorized under ESA Section 10(A)(1)(b), so sometimes the BCCP is called a "10A Permit."

A collection of documents guides BCCP implementation: Endangered Species Act Permit No. TE 788841-2; BCCP Final Environmental Impact Statement and Habitat Conservation Plan; Travis County – City of Austin Interlocal Agreement – Shared Vision; Permit Area and Fee Zone Maps; and **tiered Land Management Plans**.

These documents together provide the permit term and conditions, mitigation requirements, land acquisition areas (the **Balcones Canyonlands Preserve** or **BCP**, and the **Permit Caves**), land management and permit administration guidelines, and mechanisms by which the City and County can cover the impact of endangered species habitat loss in western Travis County and expedite development projects within the Permit Area.

The Land Management Plans are a guide for all BCCP partners' programs implementing the permit and provide "best practices" for managing BCCP-required conservation lands:

Tier I	Overview of the Preserve and Partner Responsibilities
Tier II A	BCP Land Management Guidelines (Specific Best Practices)
Tier II B	BCCP Administration
Tier II C	BCP Macrosite Requirements
Tier III	BCP individual tract plans

This plan outlines best practices for **Oak Wilt Management, Tier II A-3**.

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1.0 PURPOSE

This chapter presents terms and information about oak wilt spread and prevention on the BCP; best practices during trimming, clearing and vegetation management; and mechanical and chemical means to prevent conditions favorable to oak wilt. Infected areas and tree loss from this disease may threaten habitat quality and quantity for BCCP-covered species so detection, monitoring, and management are key management practices.

2.0 OAK WILT IN THE BCP

Oak wilt has been confirmed on the following BCP macrosites: Barton Creek (Barton Creek Wilderness Area, Barton Creek Habitat Preserve), North Lake Austin (Emma Long, Long Canyon, Cortaña), South Lake Austin (Reicher Ranch, JJ&T, Medway), Bull Creek (Jester, Canyon Creek, Sam Hamilton, Hanks, Ribelin), and West Austin (Vireo Preserve). Although not confirmed, areas being monitored with suspected oak wilt include the Pedernales (Hamilton Pool Preserve) and Cypress Creek (Nootsie) macrosites.

Confirmation is compromised by tree loss from drought, other environmental stress (e.g. adjacent development, root cutting or loss, dust), and other oak (*Quercus* spp.) issues (e.g. hypoxalon canker, oak decline), which can mimic oak wilt in current detection methods (flyover, field observation). Impact mapping and activities to manage oak wilt on the BCP are documented in the BCCP Annual Report (*Section 6.3*).

3.0 BACKGROUND

3.1 Oak Stressors in our Area

There are several tree health conditions caused by extreme environmental conditions (e.g. drought), *Hypoxalon* canker (non-aggressive, facultative saprophyte, *Hypoxylon atropunctatum*), oak decline (complex interaction of natural and human-caused environmental stresses and pests that weaken oaks over time, Wargo et. al. 1983), climate change and other stressors which may affect habitat quality on the BCP. This Land Management Plan focuses on oak wilt detection and prevention as it is the oak disease with the greatest likelihood, if undetected or unmanaged, to quickly and adversely affect covered species' habitats.

Oak wilt is caused by the fungus *Ceratocystis fagacearum* which develops in the outer sapwood in vessels or tissues that conduct water and nutrients from the roots to the leaves (Appel 2001a), is infectious and potentially affects all *Quercus* and related species in the family Fagaceae. *Quercus* species vary in resistance or vulnerability. Foliar symptoms (unseasonal defoliation, coloration), patterns of tree mortality (large clusters, unseasonal dieoff), and the presence of fungal mats are indicators of oak wilt (*Section 4.0 Symptoms and Detection*).

3.2 Oak Wilt and Endangered Species

From an economic and aesthetic viewpoint, the effects of oak wilt in urban residential areas are devastating and cost millions of dollars in property devaluation. The effect of oak wilt on the region's ecological dynamics is more complex and difficult to assess. Oak wilt threatens both the endangered golden-cheeked warbler (GCWA) and black-capped vireo (BCVI) through loss of nesting and foraging habitat, as well as habitat degradation resulting from canopy breach, increased edge, change in tree composition and altered woodland stand structure (Appel and Camilli 2010; see also GCWA Tier IIA Chapter VII and BCVI Tier IIA Chapter VIII). Impacts which reduce acreage or functionality of these species' habitats adversely affects the BCCP partners' abilities to comply with the permit and manage the BCP sustainably in perpetuity.

Oak wilt prevention practices are aimed at stopping the spread of individual infection centers. Steep and rough areas, where suitable GCWA and BCVI habitat exists, are often unsuited for all potential oak wilt suppression activities. Since oak trees are sometimes removed during suppression of individual disease centers, localized habitat degradation may occur; however, the impact of this practice on habitat quantity and quality may be insignificant compared to the beneficial effect of protecting adjacent oaks from disease spread and oak mortality.

All chemicals utilized for oak wilt control are EPA-registered, applied by state-licensed applicators, used as a last resort in the smallest effective quantities, and applied during the non-nesting season (September-February) when the GCWAs and BCVIs are on their wintering grounds.

3.3 History

Oak wilt is considered to be one of the most destructive tree diseases in the U.S. Intensive survey, research, and management programs have been carried out since the original description of the pathogen from Wisconsin in 1942 (Henry et al. 1944, Appel 1995). These previous efforts are useful in providing information on the comparative epidemiology of oak wilt in Texas and may assist in determining how oak wilt control might be best managed. The initial discovery of *C. fagacearum* in Texas was made in 1961 from diseased trees in Dallas (Dooling 1961) and was well beyond the accepted range of oak wilt (Hepting 1971). It had been thought that the oak wilt fungus could not survive in Texas because of high summer temperatures and the competitive presence of the oak canker fungus, *Hypoxylon atropunctatum.* These factors were formerly believed to limit the survival of *C. fagacearum* in the South (Gibbs and French 1980). *C. fagacearum* is inhibited or killed by temperatures exceeding 90°F (Houston et al. 1965), but in Texas it can survive high summer temperatures in the roots and boles of infected trees (Lewis 1985, Appel 1995).

Due to various reasons (e.g. misdiagnoses, late detection, disease biology, large stands of homogenous live oaks, virulent fungus, alternative methods of spread), this lethal disease spread uncontrolled throughout Austin and other areas of Central Texas for decades. Many large areas of infection within the BCP have grown beyond conventional suppression capabilities; in those areas, the only practical option is to monitor the disease and wait for natural controls such as burn out (lack of remaining host trees) or natural and manmade breaks in the terrain (escarpments, creeks or major roadways) to take effect.

In 1982, an oak wilt/decline demonstration project identified oak wilt in 35 counties, most of which lie within the Edwards Plateau, Cross Timbers, and Blackland Prairie of central Texas (Appel and Maggio 1984). In 2003, oak wilt had been confirmed in 65 counties with 6,000 oak wilt centers (Texas Forest Service 2004). Currently, it is known to occur in 22 states and within 74 Texas counties – 67 in central Texas, 7 in west Texas (Texas Forest Service 2013).

Currently, there is no cure for the disease, although there are several measures available to prevent and manage the spread of (suppress) oak wilt.

3.4 Susceptibility

Of the approximately 64 North American oak species (*Quercus* spp.), 53 are native to Texas (Kartesz 2003). All are presumably susceptible to oak wilt fungus to some degree, but some species are more resistant than others.

Red oaks - particularly Spanish oak (*Q. Buckleyi),* Shumard oak *(Q. shumardii),* blackjack oak *(Q. marilandica),* and water oak *(Q. nigra)* - are extremely susceptible. Spanish oaks in Texas are severely affected by oak wilt in Texas and are known to support fungal mat formation.

White oaks, including post oak *(Q. stellata),* bur oak *(Q. macrocarpa),* and chinquapin oak *(Q. muehlenbergii),* are resistant to the fungus and rarely die from oak wilt; however, BCP staff have observed dead shin oaks *(Q. sinuata* var. *breviloba)* within oak wilt centers. Live oaks *(Q. virginiana* and *Q. fusiformis)* are intermediate in susceptibility, but are most seriously affected due to their tendency to grow from root sprouts and form vast interconnected root systems that allow movement (or spread) of the fungus between adjacent trees. More live oaks are lost to oak wilt than any of the other species. Live oaks are the primary hosts of *C. fagacearum* in Texas (Appel and Maggio 1984, Appel 2001a), the only state reported to have oak wilt in a natural live oak population.

3.5 Disease Transmission

Oak wilt can spread in three ways:

- above ground long distance transmission from insect vectors which enter vulnerable oak species through untreated wounds (limb, trunk or root);
- below ground local spread between adjacent trees through root grafts or common root systems; and by

- firewood cut from oak wilt infected trees (Johnson 1994, Juzwik 2000, Appel et al. 2003).

The limitations of each of these transmission methods may result in the failure of *C. fagacearum* to cause catastrophic losses (Gibbs and French 1980, MacDonald and Hindal 1981).

3.5.1 Above Ground (Inoculum Production and Insect Transmission)

Insects can transmit the oak wilt fungus into untreated pruning cuts and wounds (e.g **nicks and scrapes during construction on trunk, limbs and exposed roots**) on susceptible oak species. Sap-feeding nitidulid beetles (Order: Coleoptera, Family: Nitidulidae) are vectors of the oak wilt fungus (Dorsey et al. 1953, Norris 1953, Jewell 1956, Himelick and Fox 1961). Long distance transmission of *C. fagacearum* by insect vectors is especially troubling because it initiates new centers of infection and is less predictable. In Texas, fungal mat formation is known to occur only on diseased Spanish oaks and blackjack oaks (Appel et al. 1987). No fungal mats have been observed on infected live oaks. Mat formation on infected red oaks is influenced by season of infection, tree condition, temperature, and rainfall (Gibbs and French 1980, MacDonald and Hindal 1981).

Mat production is usually greatest during the spring, when trees are most susceptible and nitidulids are most active, but they also form in the fall (Appel and Lewis 1985). In the late fall and early spring, oak wilt fungal mats and masses of oak wilt spores are produced beneath the bark of diseased red oaks. Individual fungal mats produce spores for only a few weeks. Fungal mats are most commonly formed on standing trees, but they can also be formed on logs, stumps, and fresh firewood cut from diseased red oaks (Juzwik 2000, Appel et al. 2003). Moderate temperatures and high sapwood moisture content are conducive for mat formation (Appel et al. 1987).

Fungal mats bearing oak wilt spores can appear on red oaks several months after the trees die from disease. Even after their deaths, red oaks may still contain enough moisture in their trunks to support development of the reproductive parts of the fungus, called fungal or mycelial mats. These spore-producing fungal mats crack the tree bark. The mats have a fermenting, sweet odor and they are a suitable food source that attracts insects, especially the sap-feeding nitidulid beetles. Oak wilt spores adhere to the insect's bodies as they feed. After feeding on the mats, contaminated nitidulids emerge and disperse. These beetles are also attracted to oozing plant sap that collects at the surface of a fresh cut from pruning or wound (broken limbs) on healthy trees (both red oaks and other susceptible oak trees). While feeding on these trees, the beetles deposit the spores from the fungal mats and new infection centers are formed.

A wound is susceptible to infection for the first few days after the cut or wound occurs. In this way infection can result by vector transport from infected red oaks to uninfected oak trees. Presumably, in this manner the fungus is transmitted to live oaks over long distances (Dorsey et al. 1953, Juzwik and French 1986, Juzwik 2000).

Early diagnosis and proper disposal of diseased red oaks is therefore critical to limiting the number of new infection centers. Nitidulid beetles are present most of the year, but numbers are greatest and these insects are most active in the spring and early summer, which also coincide with periods of maximum fungal mat formation in Texas (Appel et al. 1987, Juzwik 2000, Appel 2001a). Therefore, **pruning and other kinds of wound-inducing practices in spring and under conducive weather conditions should be avoided** (*Section 5.1.1 Pruning Practices*).

3.5.2 Underground (Root Transmission)

Studies have indicated that fungal mats do not form on white oaks, nor do they form on infected live oaks. Pathogen spread among live oaks is believed to be limited to transmission between diseased and healthy trees through root grafts and common root systems. Root sprouting and root grafting are characteristic for live oaks. The local transmission of *C. fagacearum* through functional root connections is probably responsible for most oak wilt losses of live oak in Texas (Appel 1986, Appel 2001b).

Root graft transmission: Connections may form when the roots of two adjacent trees grow together and produce a union of xylem tissues. Disease centers in Texas on live oak can involve thousands of trees and encompass dozens of hectares. Stand density and soil depth has been shown to influence tree-to-tree spread of the pathogen through root grafts (MacDonald and Hindal 1981).

Common root system spread: Several live oaks are capable of sharing one common root system. When one live oak becomes infected, all live oaks sharing the same root system have the potential for contracting oak wilt. This contributes to the rapid rate of disease spread and the large size of disease centers among the live oaks. Live oaks form rhizomes for vegetative propagation through root sprouting (Muller 1951). If the sprouts maintain common root connections through maturity, they will provide an additional mechanism for transmission of oak wilt. As in other states, the pathogen in Texas is consistently transmitted through adjacent live oaks in a highly predictable manner forming discrete, well-delineated centers (Gibbs and French 1980). The potential size of cloned live oak stands is unknown.

Tree-to-tree spread in central Texas may progress up to 100 feet per year and can result in very large centers of disease, up to 100-200 acres. The fungus continues to spread outward from the originally infected tree, involving more and more trees. Diseased stands are often large, discrete, and comprised of hundreds of trees in various stages of disease development. Such a group of dead and dying trees is called an infection (oak wilt) center. Spread through root connection can be prevented by mechanically trenching around infected trees, thus physically separating the trees.

3.5.3 Firewood (Transmission of Oak Wilt by Logs)

Firewood cut from diseased red oaks (Spanish, Shumard, blackjack and water oak) can spread oak wilt fungus to new areas (Johnson and Appel n.d.) if the cut wood contains fungal mats and/or insects carrying the spores of the oak wilt fungus. Fungal mats may already be formed on trees at the time of cutting or may form during winter while logs are stored in the woodpile.

Sap-feeding beetles contaminated with the oak wilt fungus may also be moved with firewood, including red oak logs as well as live oaks (Johnson and Appel, n.d.). The beetle would have to have fed on a mat and then migrated to a live oak or to a tree that was cut for firewood. While the firewood is stacked, the beetles may move out of the logs and enter nearby otherwise healthy trees that have been wounded or pruned (Johnson and Appel). Fungal mats are not found on firewood from oak wilt diseased live oak, but special care should be taken with all oak firewood (*Section 5.1.4 Firewood* in *Prevention and Suppression*).

Red oak firewood should be avoided. On the firewood cut from infected red oaks that die in late summer, fall and during the current winter, fungal mats can be formed and there is a potential of spreading the fungus. On red oak trees that die in late spring and early summer, the fungus does not tend to form fungal mats because of high summer temperatures, and the wood will be too dry to support mat formation. When the moisture percentage is below 14%, the wood is no longer capable of supporting the growth of the oak wilt fungus (Johnson 1994).

Smoke from burning diseased logs does not spread the fungus to nearby trees. Heat from the fire kills all spores or beetles that might be present.

4.0 SYMPTOMS AND DETECTION

On live oaks, foliar symptoms of the disease are distinctive when present and can be identified by distinctive yellowing or browning along the veins of the leaf (chlorosis or necrosis) or dead tissue at tip of the leaf. The most reliable, diagnostic foliar symptoms of oak wilt on live oaks are veinal necrosis, interveinal chlorosis and tip burn (Appel and Maggio 1984, Appel et al. 2003). Symptom development is the most rapid during spring and fall (Billings and Cameron 1987). Oak wilt in live oaks may also be recognized by patterns of spread in groups of trees and rates of crown deterioration (Gehring 1996). The oak wilt pathogen spreads rapidly from diseased trees to adjacent, healthy trees through root connections forming distinct centers of infection. Once live oaks are infected, most gradually drop leaves and die over a period of two months to two years. Some live oaks survive for many years in various states of decline. Other fungi such as *Hypoxylon* spp. and *Cephalosporium* spp. may colonize weakened trees (Johnson and Appel 1984). In rare cases, some do recover from the disease. It is estimated that 5-20% of the live oaks infected survive the oak wilt because their roots are not connected or because they have some natural resistance (Appel et al. 1986).

On red oaks, symptoms are less distinct and harder to recognize. The first foliar symptoms observed on red oaks (Spanish and blackjack oaks) are flashing.

Flashing, or browning, occurs when the leaves on a shoot or branch suddenly turn brown or bronze-colored during the growing season. Typical foliar oak wilt symptoms in deciduous oaks include water soaking and browning or bronzing of leaf tips and margins (MacDonald and Hindal 1981). Leaves turn pale green and then brown, while remaining on the tree for a while. Sometimes the leaves have a wilted, water-soaked appearance and may be quickly shed. For most members of the red oak group, nearly the entire crown shows symptoms soon after the disease is evident. Once infected with oak wilt, red oaks die quickly, two weeks to several months. Red oaks do not survive once infected with oak wilt. Diagnosis of oak wilt in the field depends on the presence of the foliar symptoms and fungal mats, and the patterns of mortality caused by fungal spread. Visible symptoms of oak wilt are not always present.

C. fagacearum confirmation is difficult from only field observations or only laboratory testing; therefore, mortality pattern documentation over time, samples and laboratory testing, and monitoring *combined* is the best way to determine disease presence. (Texas Forest Service 2013). Laboratory tests are recommended to help diagnose fungal infection, along with other field symptoms (foliar, mortality patterns). Samples can be submitted to the Texas Plant Disease Diagnostic Laboratory (Texas A&M Agrilife Extension 2010, contacts and form).

5.0 PREVENTION AND SUPPRESSION

Currently, there is no cure for oak wilt. The only measures against this disease are **prevention** (field practices to help deter the introduction of fungal infection) and **suppression** (practices to contain and prevent the spread of infected sites). Prevention and public engagement are still the best measures land managers have to protect ecological integrity. Preserve managers should share information about techniques and stay abreast with current literature and strategies which may prove to be economical, environmentally friendly, and applicable on a large scale. BCP staff need to work together to share their experiences with other agencies as well as regularly update this document as information, prevention and suppression evolve.

5.1 BCP Oak Wilt Prevention

5.1.1 Pruning Practices: Timing, Tools, and Treatment

In certain seasons (temperature-dependent), a combination of spore mat production, insect activity and pruning can enhance oak wilt vulnerability and infection potential, a deadly combination. BCP land managers employ **recommended practices** for appropriate timing, tool use, and cut-treatment when pruning or cutting oak trees.

Oak trees should not be pruned in the BCP during the fall or spring, when fungal mats are forming and nitidulid beetles are most active. The best time to trim oaks to avoid contracting oak wilt is during the hottest months of the summer (typically, July through September) and in the coldest weeks of winter (typically within November through February). On the BCP, habitat restoration work can extend through February without impact to bird breeding season; however, even in "typical" winter months with windows of opportunity, **trimming or pruning should be limited to extreme temperature days**. During extreme temperature periods, the insects that can transport the oak wilt spores are the least active.

When pruning or cutting oaks, it is recommended that **tools be sterilized with either Lysol aerosol disinfectant or a 10% bleach solution** ideally between each cut on different trees and at a minimum after/upon leaving the immediate area. Surface sterilization of pruning tools is highly recommended when moving from one red oak to another red oak and from live oaks sharing one common root system to a new group of live oaks sharing another common root system.

All pruning cuts or other wounds to oak trees, including freshly-cut stumps and damaged surface roots, should be **immediately** treated **during all times of the year** with an approved tree wound dressing/sealer (Appel et al. 2003). Beetles are attracted to plant sap that collects at the surface of a fresh cut or wound of a healthy tree. A coat of tree wound paint makes fresh wounds unattractive to the beetles that come to feed on the sap, either by masking the smell or by preventing spores from reaching the wound. The paint also acts as a barrier, which stops fungal spores carried by insects from entering the wound.

BCP land managers are encouraged to create program and organization policies which reflect these best practices and align with each other to guide day-to-day operations on and adjacent to the Preserve.

5.1.2 Public Education and Contractor Guidance

Ongoing and regularly updated outreach by BCP land managers and central Texas forestry professionals to homeowners, landscape and development businesses, and infrastructure providers is essential to prevention. The public, especially BCP-adjacent landowners and right-of-way managers with corridors next to or through the BCP, must have an awareness of oak wilt and understand that treatment and prevention are a long-term project and shared responsibility. Ideally, practices *adjacent to* the Preserve align with prevention and suppression measures *on* the Preserve. BCP land managers work closely with infrastructure providers, land clearing crews, and contractors working on or adjacent to the BCP to ensure prevention practices are followed (*5.1.1. Pruning Practices*). Contracts for clearing, pruning, or cutting vegetation for road maintenance, fence installation or maintenance, construction, easement maintenance or utility upgrades, tree maintenance, shaded fuel breaks, or similar work should include specific conditions that align with this chapter's guidance.

5.1.3 Planting Resistant Species and Diversity of Species

Species composition in woodlands and forests influences oak wilt incidence (MacDonald and Hindal 1981). The disease is prevalent in Texas where species diversity is low, as in homogenous live oak stands in central Texas (Appel 1986). Plantings to augment existing site diversity, habitat restoration or creation projects, and recommendations for landscape installations in areas known to be affected by oak wilt should reflect central Texas native tree species (e.g. cedar elm, Texas ash, escarpment black cherry, Arizona walnut, hackberry, Mexican plum, rusty blackhaw, Ashe juniper, Texas mulberry), improve the site diversity if appropriate, and include resistant oaks (e.g. bur, chinquapin, lacey) if they are site- and system-appropriate. These are suggested trees that can be planted in most areas where oak wilt is a problem. This will reduce the chance of reoccurrence of oak wilt or similar disease problem.

The long-term fate of live oaks and red oaks that are replanted in oak wilt infection centers is still uncertain. Further research and observation will determine if these susceptible oak species can become infected over time through root grafts with the residual diseased root systems. Additionally, no research has been done to determine if particular species lost to oak wilt can be "replaced" with resistant oak species to equal the lost oaks' habitat values (structure, forage support, seasonal availability) and meet species' needs in the BCP.

5.1.4 Firewood

Firewood is not collected from or burned on the BCP; however, this information is relevant to BCP land managers' guidance to infrastructure providers, adjacent home owners, and others who may use BCP management as an example. Oak wood, especially red oak, should *not* be used as firewood. Any red oak wood could contain fungal mats and/or insects carrying the spores of the oak wilt fungus.

For Public Outreach and Awareness - steps to reduce the risk of oak wilt introduction from cut firewood:

1. If possible, find out exactly where the wood is from to ensure that it has not come from an area infected with oak wilt.
2. Make every effort to collect or obtain only wood that is properly seasoned (dead/dry). Ensure this by looking for cracks developing on the cut ends and loose bark.
3. Do not harvest, collect, buy or transport red oak varieties (Spanish Oak or Blackjack Oak) for firewood which may contain infectious oak wilt spores.
4. Never stack firewood from trees known or suspected of being infected with the oak wilt fungus near healthy trees. As an added precaution, cover the wood with *clear* plastic with the ends properly tucked and sealed. *<u>Do not use black plastic</u>.* Clear plastic traps the insects, and unlike the use of black plastic, the insects cannot use light holes to escape.
5. Firewood from unknown origins should be burned during the coldest winter days and not allowed to carry over to the next season.

6. If you are planning to harvest firewood, attempt to cut it in the hottest part of the summer and let it dry in full sun on site before transporting it to urban areas.

5.2 Recommended Suppression Practices on BCP

5.2.1 Host Elimination: Red Oak Removal

This applies to infected red oaks. Infected red oaks are treated by several methods that stop development of fungal mats on those trees and reduce the possibility of disease spread by insects (long distance disease transmission). Methods of suppression treatment on infected red oaks include removal or felling of infected trees and chipping or burying them immediately. When felling a tree, it should be bucked/cut into pieces about 12-16 inches in length. It is recommended that large logs from the trunk of larger trees (logs with a DBH of ≥8 inches) be stripped of their bark, or semi-girdled, in an attempt to reinforce the drying process. All stumps of felled trees are to be girdled to the soil or rock. Other methods include deep girdling and lower bark removal or applying herbicides. An approved silvicide (including but not limited to Garlon® 3A, Garlon® 4 and Roundup®) can be applied according to label instructions. The preferred method of applying silvicide is to inject the chemical in the base of all diseased red oaks displaying symptoms using the axe frill method (Texas Forest Service 1991). All silvicides (herbicides) are used only if there is no other way of removing diseased red oaks. They must be used by certified pesticide applicators. All chemicals applied during project activities are EPA-registered, and should be used as a last resort and in small quantities. Any treatment that hastens the drying of the wood tissue under certain moisture content will tend to reduce sporulation. Even though Texas red oaks die quickly from oak wilt, the trees still have enough moisture in the roots and trunk for fungal mat production. Therefore it is very important to destroy diseased red oaks as soon as the symptoms are recognized. If done during the early stages of the disease, spores will not be produced.

5.2.2 Root Separation: Trenching

Trenching continues to be the preferred primary control method to reduce root transmission of the oak wilt fungus. Trenching is not always totally effective, but the technical guidelines are continually being modified to increase the success rate. Two of the major changes have been to increase the distance of the trench from the infection (~100 feet) and to increase the depth of a trench (>48 inches, preferably 60 inches). Other changes involve the use of existing barriers, more back-up and secondary trenches, and the elimination of silvicide barriers (Gehring 1992). Silvicide barriers were used in the early phase of the oak wilt suppression. The intended purpose of silvicide was to kill the root system, but tests show this does not stop fungal spread, and also, silvicide was causing mortality of adjacent healthy trees. Silvicides are no longer recommended for suppression, except to hasten the death and drying out of red oaks that cannot be removed and destroyed in a timely manner. Proper placement of the trench is critical for successful protection of uninfected trees. There is a delay between colonization of the root system by the fungus and appearance of symptoms in the crown; therefore, all trees with symptoms are carefully identified. The trenches are placed a minimum of 100 feet beyond these symptomatic trees, even though there may be healthy trees at high risk of infection inside the trench (Juzwik 2000, Appel 2001a, Appel et al. 2003). Recommended depth is four to five feet, in order to prevent further underground spread of oak wilt. This method of control has proven to be 70% effective statewide. In some instances, trenches greater than five feet deep may be required to ensure control in deeper soils where roots may still be present. In addition, water-permeable inserts can be placed in the trench, which have been shown to extend trench longevity (Wilson and Lester 2002). Oak wilt infection centers are more easily suppressed when treated early, before they become too large.

5.2.3 Intravascular Injection with Propiconazole in Live Oak

Injecting the fungicide propiconazole (Alamo®) into the xylem may sometimes slow its progression (Lewis and Brook 1985, Osterbauer and French 1992, Eggers et al. 2005). According to Dr. David Appel, although propiconazole can be considered sufficient to recommend for oak wilt control in live oaks, there are several limitations to this use of injection for disease management. Propiconazole injections do not act as a barrier to inhibit transmission of the pathogen through root connections between treated and untreated trees; many treated trees clearly become infected. Furthermore, propiconazole injections in live oaks should be used in conjunction with other control techniques to ensure that all available options are used to manage the disease and reduce losses (Appel, D.N. 2001b). Propiconazole injections are used on a very limited basis within the BCP, for example trees that have historical or other significance.

The fungicide propiconazole (Alamo®) is injected into the tree's water-conducting system through small holes drilled into the root flares at the base of the newly infected trees while crown loss is still minimal. Uninfected, healthy live oaks at risk to infection by root connections are the best candidates for treatment. These preventative treatments will yield better results than therapeutic injection of infected trees in the early stages of disease (Appel 1996, Appel 2001b, Eggers et al. 2005). These practices are usually done on high value live oaks (oaks impacting real estate property values), usually in combination with trenching. In some instances re-treatment with the fungicide is needed 12-24 months after the first fungicide injection.

Although this is not considered as a true suppression technique because it does not suppress the spread, it does help reduce the impact of oak wilt in the long term. Fungicide can be used to save individual trees, but it does not kill the fungus in the roots, and therefore, does not keep the disease from spreading from tree to tree. This treatment is used best in conjunction with trenching or to protect individual high-value trees. Foliar symptoms can be used in selecting trees as candidates for preventative or therapeutic treatments.

Treatment success depends on the health condition of the candidate tree, application rate, and injection technique. Injection should be done only by trained applicators. Treatment is successful if started in early stage of infection when $\geq$80% of crown canopy is still alive. Both silvicides and fungicides are applied only to lower bole sections of oak trees in either a frill girdle or a pressure injection treatment.

5.2.4 Roguing Trees: Buffer Creation

Roguing is the process of sacrificing trees to create a buffer in front of an advancing oak wilt center and is rarely used within the BCP. It can be accomplished using a bulldozer, or other heavy equipment, to remove healthy trees and roots. Roguing can also be accomplished by cutting down buffer trees, and then applying an herbicide ("chemical roguing") to the stumps to kill as many of the roots as possible. Roguing is only effective if no root grafts remain between infected and uninfected trees. Since neither bulldozing nor chemical roguing will generally sever all root grafts, this method should only be used if trenching is not an option; however, in conjunction with a trench, buffer tree roguing has been used (Gehring 1992) to reinforce the barrier of the trench.

6.0 SURVEY, MONITORING, AND REPORTING

6.1 Daily Field Observations

In the course of day-to-day operations and field work, biologists, researchers and contractors are encouraged to look for and report any suspected oak wilt to BCP staff and a local oak wilt specialist or forester with field experience in diagnosis. The Texas Forest Service Oak Wilt Coordinator in Austin is available to advise agencies with oak wilt problems. Reporting is encouraged through public outreach efforts as well.

6.2 Survey and Monitoring Efforts on BCP

City of Austin Wildlands BCP staff and Texas Forest Service fly the regions of Travis County known to be vulnerable to oak wilt and map centers of the disease and its annual spread. Travis County BCP staff compares City findings with suspected oak wilt centers they have identified through filed visits and aerial imagery. Other BCP land managers also document oak wilt centers and spread on their sites. This information is discussed as needed at Land Managers' Meetings and feasible actions are taken to suppress the spread. Ideally, BCP teams and Texas Forest Service Oak Wilt Specialists work together annually in June and July to focus efforts and share resources for detection (survey), monitoring (existing), and suppression and to respond when diseased red oaks may be "flashing" (turning red or brown in an unexpected season). Untreated trees immediately outside of trenched areas will be monitored for several years across varying weather patterns to ascertain if suppression worked. If the disease appears to have breached the trench, new trenching should be repeated (Appel et al. 2003).

6.3 Annual Reporting

The BCCP Annual Report is delivered to US Fish and Wildlife Service each January, covering activities of the previous fiscal year.

All oak wilt detection, monitoring and treatment activities on the BCP are compiled and reported in the BCCP Annual Report. If aerial survey, LIDAR or other digital, or field data is collected and analyzed in a year’s efforts, maps will be included in the Annual Report.

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