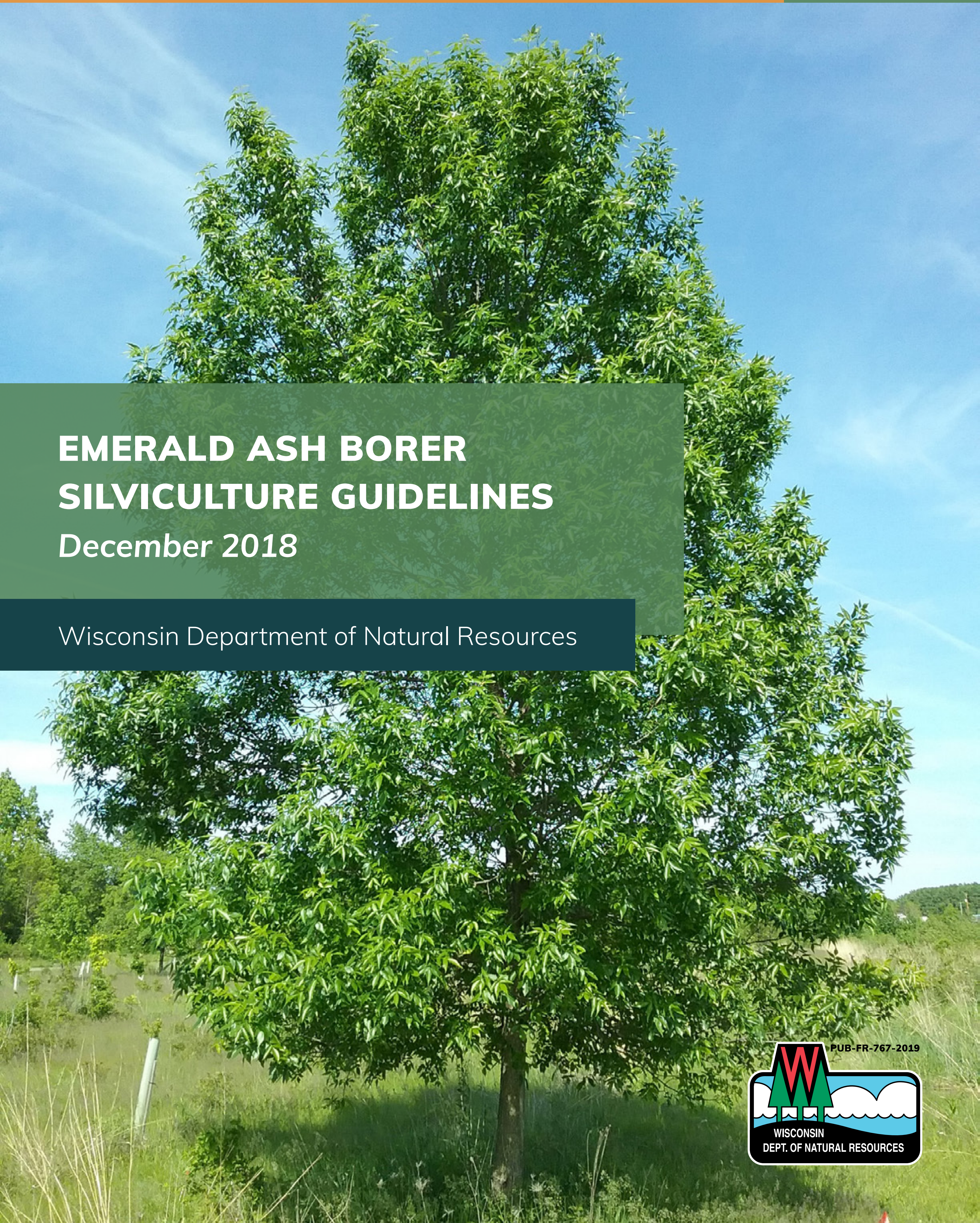

EMERALD ASH BORER SILVICULTURE GUIDELINES

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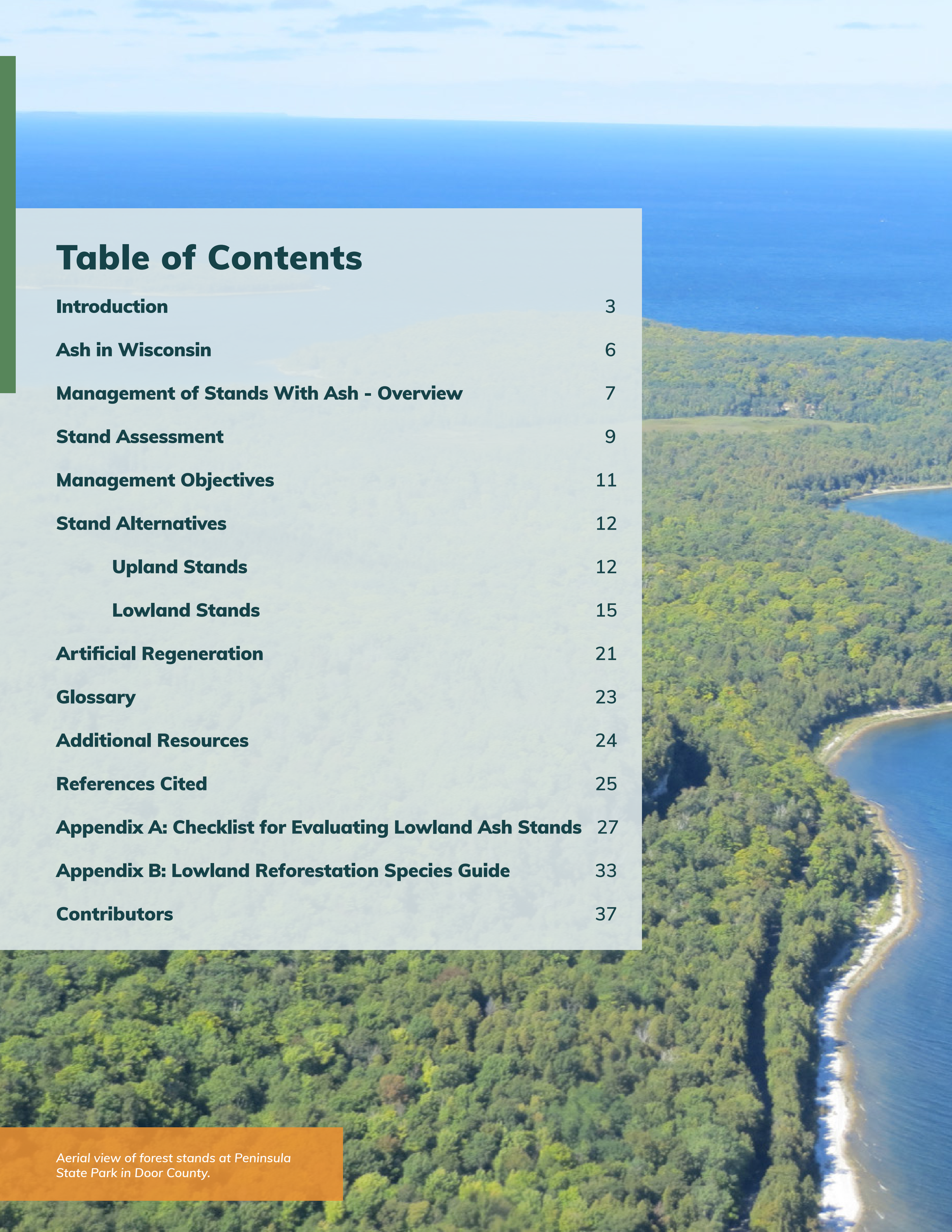

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Aerial view of forest stands at Peninsula State Park in Door County.

Introduction

EAB adult.

PURPOSE OF THE GUIDE

This guide is intended to help resource managers make informed stand-level decisions to manage forests that are not yet infested by emerald ash borer (EAB), *Agrilus planipennis*, as well as implement salvage harvests and rehabilitation in stands that have already been impacted by EAB. The guidelines do not address landscape-level management or the treatment of individual trees with insecticides to prevent mortality from EAB. Landowners are strongly encouraged to consult with a professional forester about managing EAB in their forests. If deviating from their current management plan, landowners enrolled in tax law or incentive programs should work with the appropriate specialist to ensure compliance with program requirements. Sustainable and sound forest management practices should be followed whenever possible.

EAB gallery with characteristic winding pattern.

Land managers should carefully review existing management plans, evaluate long-term management options, and determine which species and silvicultural practices are suitable for their properties. Preparing a stand for EAB impacts may allow a stand to remain adequately stocked with non-ash species, and able to meet management objectives if the remaining ash die or are harvested. In the short term, an ash component will help to maintain species diversity and provide ecological benefits.

USE OF THE GUIDE

This document is intended solely as guidance, and does not contain any mandatory requirements except where requirements found in statute or administrative rule are referenced. This guidance does not establish or affect legal rights or obligations, and is not finally determinative of any of the issues addressed. This guidance does not create any rights enforceable by any party in litigation with the State of Wisconsin or the Department of Natural Resources. Any regulatory decisions made by the Department of Natural Resources in any matter addressed by this guidance will be made by applying the governing statutes and administrative rules to the relevant facts.

HISTORY OF EAB

Emerald ash borer is an exotic insect that was first identified in southeast Michigan in 2002. In 2008, EAB was detected in Ozaukee and Washington Counties in southeast Wisconsin. Since then, EAB has been found in many areas of the state. EAB has also been found in numerous states and several Canadian provinces. Visit the Wisconsin EAB website to see where EAB has been confirmed.

The entire state of Wisconsin is currently under a state-issued emerald ash borer quarantine (s. 94.01, Wis. Stats.) even though the insect has not yet been found in all 72 counties. Quarantine restrictions may still apply to ash wood movement to another state (7 C.F.R. Part 301). In addition, other quarantines to prevent the movement of gypsy moth are still applicable to wood movement into western Wisconsin counties and many other states (s. 94.01, Wis. Stats. and 7 C.F.R. Part 301). For updated quarantine and regulatory information, visit the Wisconsin EAB website.

IMPACT ON ASH

Emerald ash borer is expected to kill more than 99% of white, green and black ash in Wisconsin, regardless of a stand's size, ash density or species composition (e.g. Knight et al. 2010; Klooster et al. 2014; Smith et al. 2015). Emerald ash borer is capable of infesting trees more than one inch in diameter, and even healthy ash trees decline and die within a few years of becoming infested. In the absence of active management, EAB impacts will be proportional to the amount of ash in a stand. Insecticide treatments can prevent or reverse tree decline in moderately-infested ornamental trees but are not practical for ash in forests.

RECOMMENDATION: Prepare for more than 99% mortality of susceptible white, green and black ash.

Mature EAB larva with bell-shaped segments.

White ash is reported to be less preferred by the insect than black or green ash, although studies in Michigan found nearly 100% mortality in all three species when EAB populations were high (Herms and McCullough 2014). Blue ash, which is present in a few southeast Wisconsin stands, has been observed to be more tolerant of EAB than other Wisconsin ash species (Herms and McCullough 2014).

Most mortality in an EAB-infested stand occurs within a period of a few years (Herms and McCullough 2014). Knight et al. (2013) found that ash trees died faster in stands with lower ash density, on mesic sites, in trees initially exhibiting dieback, and in intermediate and suppressed trees. The smallest susceptible ash trees tend to die last (Herms and McCullough 2014).

The growth of non-ash species in mixed stands typically increases due to EAB mortality, as these species take advantage of gaps created by dead ash (Burr and McCullough 2014; Costilow et al. 2017).

Ash mortality in Washington County.

D-shaped exit holes are approximately 1/8 inch in size.

Outer bark removed by woodpeckers looking for EAB larvae in an infested ash.

Ash regeneration from seeds and sprouts is present on the landscape, and ash may persist if it can sprout or produce seed before being killed by EAB. However, ash is unlikely to be as common as it currently is (e.g. Kashian 2016), and can be re-infested by EAB once it grows to a suitable size (e.g. Kashian 2016; Duan et al. 2017).

Scientific studies have found little natural resistance to EAB in the native ash population, but long-infested states report that a small proportion of ash trees have remained alive after the surrounding ash have died (e.g. Aubin et al. 2015; Kashian 2016; Robinett and McCullough 2016). At present, it is not practical for a forester to predict which individual trees will remain alive. Many of these "lingering ash" are believed to be resistant to EAB or tolerant of infestation, and may become an important resource for restoring ash to the landscape. Foresters are encouraged to report the locations of these trees, if observed, to DNR forest health staff.

Once the initial wave of tree mortality has occurred, EAB populations decline dramatically. Low numbers remain in small, regenerating ash as well as surviving, larger trees (Burr and McCullough 2014; Klooster et al. 2014; Burr et al. 2018). Ongoing, low-level ash mortality continues in these areas. The long-term fate of ash will depend on the interactions between ash regeneration, EAB, and the natural enemies of EAB (Klooster et al. 2014). Studies are ongoing.

SIGNS AND SYMPTOMS OF AN INFESTATION

EAB-infested trees usually have multiple signs and symptoms of infestation if they have been infested for several years. These include thin foliage and/or dieback in the upper crown, epicormic sprouts on the stem or at the base, 1/8" D-shaped exit holes, S-shaped larval galleries under the bark, and heavy woodpecker activity. EAB larvae are up to 1.5" long and have distinctive bell-shaped segments. Similar signs and symptoms can be due to other causes, such as infestation by other wood and phloem-boring insects, phytoplasma or root injury/infection. For more information, visit the Wisconsin EAB website.

Ash in Wisconsin

Wisconsin's forests contain about 890 million ash trees greater than 1 inch in diameter, comprising approximately 8% of all forest trees in this size range. Ash is also a common street and yard tree.

- White ash (*Fraxinus americana*) is present throughout the state, most commonly as a primary species within the northern hardwood cover type. White ash grows on a variety of sites but is most frequently found on fertile, well-drained soils. In general, white ash is less favorable for EAB than green or black ash.

- Green ash (*F. pennsylvanica*) is most common in southern Wisconsin but is found throughout the state. It may form pure stands or grow in association with black ash, red maple, silver maple, swamp white oak and elm. Green ash is most common in and around stream banks, floodplains and swamps, although it may grow as an associate in upland hardwood stands.

- Black ash (*F. nigra*) is most frequently found in northern Wisconsin but is distributed over the entire state. It is most common in swamps where it is the most abundant species, although it is also found in other wet forest types.

- Blue ash (*F. quadrangulata*) is a threatened species that is only found at a few upland sites in Waukesha County, but is common in states farther south. It is not of commercial importance in Wisconsin. Blue ash is the native Wisconsin *Fraxinus* species most tolerant of EAB infestation, and many blue ash trees remain alive in long-infested states.

- Mountain ash (*Sorbus americana* and *S. decora*) is not a "true" ash (*Fraxinus*) and is not attacked by EAB.

All ash species serve an ecological value of some kind. Seeds are eaten by several bird species and smaller rodents. Ash also provides browse opportunities, cavities and cover value for a wide variety of wildlife. Black and green ash, sometimes being the only significant tree species in wetlands, maintain evapotranspiration in the area and prevent swamping.

Open-grown ash in winter.

Green ash at peak color in Winnebago County.

Sawing small ash with a portable sawmill.

ECONOMIC USES

In Wisconsin, ash represents approximately 4% of pulpwood production and about 5% of sawlog production (2013 data). Ash is used for multiple purposes, including lumber, paper and woodworking pieces. Wisconsin's ash grade lumber is mostly sent to cabinet, flooring, trim and handle manufacturers in the Midwestern U.S. Ash log and lumber export is also a major market for many Wisconsin wood products companies. The low-grade lumber and cants mostly go to pallet manufacturers throughout the region. Other commercial uses for ash include firewood, animal bedding and baseball bat production. For more information about the uses of ash, see the links in the "Additional Resources" section of this guide.

Management of Stands With Ash – Overview

The continued spread of EAB has increased the urgency to address ash management, especially in stands where ash is more than a minor component. Harvesting of ash is intended to capture economic value and establish suitable growing conditions for non-ash species. It is not done with the expectation of slowing EAB spread.

Ash marked for harvesting in Fond du Lac County.

Pre-salvage and salvage of ash, as well as encouraging non-ash regeneration, will be a priority in many stands. Land managers will likely have more control over the future composition and structure of their stands if active management is started as soon as practical, as opposed to waiting until EAB impacts properties or local areas. Starting management activities early can help address the uncertainty about how quickly EAB will spread and impact a previously uninfested stand.

RECOMMENDATION: Begin managing forests for emerald ash borer as soon as practical in order to increase management options, maximize economic value, and reduce future EAB impacts.

When timing management activities, it is important to consider factors that may cause an unexpected change in the financial value of ash timber. These factors include unpredictable winter access to lowland sites, fluctuating wood markets, and the length of time required to set up and administer a timber sale. Prioritization of stand activity will be important to landowners with large, geographically-scattered properties.

It is important to harvest ash trees prior to EAB infestation if a land manager intends to capture maximum economic value. Published literature and local experience have found a loss of timber value following EAB infestation, primarily due to fungal staining. The amount of value loss increases with the length of time that the trunk of a tree is EAB-infested. Fungal decay may already be present. In addition, EAB-infested or killed ash can be a safety hazard due to reduced structural integrity.

Black ash log pile.

Dead trees have a significantly lower moisture content (Persad 2013), so wood that is sold by weight will typically have limited value. In addition, accelerated oxidation staining and fungal discoloration can occur in warm weather if trees are left on site too long after being harvested.

If EAB is known to be in the local area, it may be appropriate to accelerate harvesting schedules because there is not much time to pre-salvage ash before it becomes infested. EAB infestation may turn an economically-viable timber sale into one that is no longer financially viable, especially if the trees cannot be harvested before log degradation.

Landowners who proceed with an ash harvest must comply with all state and local statutes and rules regarding timber harvests, including a requirement to submit a county cutting notice when applicable (s. 26.03(1m), Wis. Stats.).

ASH RETENTION

Even though EAB is expected to kill more than 99% of ash trees, this does not mean that they should all necessarily be harvested. Consider retaining scattered ash trees for ecological purposes, species diversity, wildlife habitat or seed production. It may be appropriate to retain smaller ash trees to temporarily provide growing conditions for non-ash regeneration, control wetland hydrology, or inhibit the growth of invasive plants.

Small ash (<6" dbh) are more likely to produce basal sprouts than larger trees (e.g. Kashian 2016), and may help to retain the presence of ash on the landscape. Many of the retained ash can be expected to produce seedlings and sprouts that may be aided by introduced biological controls. The current distribution of these biological controls is poorly known, however.

Mixed-species bottomland forest in Racine County has retained dead ash for wildlife habitat.

Stand Assessment

Before deciding on a management strategy for a forest stand, it is important to evaluate the characteristics of the stand and site in terms of stand growth, quality and potential. It is highly recommended that a forester assess a stand with the considerations found in Table 1 before deciding on a management strategy. Additional information can be found in the DNR Silviculture Handbook, Checklist for Evaluating Lowland Ash Stands (Appendix A), Lowland Reforestation Species Guide (Appendix B), Wetland Habitat Typing publications, and other information sources in the "Additional Resources" section of this guide.

Assessing a forest stand in Sheboygan County.

RECOMMENDATION: It is important to assess the characteristics of a stand and site before selecting a management strategy. Altering an existing management plan may be appropriate if a stand's situation has changed. Management objectives should be identified within the practices of sustainable forestry.

PROXIMITY TO KNOWN EAB INFESTATIONS

An important consideration affecting the choice of silvicultural alternatives for an ash stand is the proximity to known EAB infestations. Visit the Wisconsin EAB website for information about known locations of the insect. If EAB is known to be in the local area, it may be appropriate to accelerate harvesting schedules. When EAB populations are high, spread can be several miles per year and ash impacts may become common within a few years of a first detection in the local area.

Single infested ash with a thinning canopy in Sheboygan County.

Once EAB is detected in an area, it may take several additional years for the population to build to a level that will cause significant tree mortality. However, this length of time is variable and often difficult to predict because it depends on several factors such as infestation age, local spread rates, local climate, and the proximity of undetected infestations. At a county level, a significant increase in ash mortality generally begins 6–7 years after EAB is first detected, and continues until most ash are killed (Morin et al. 2017). Knight et al. (2013) found that stand-level ash mortality was more than 99% within six years of first infestation. The study also found that half of the ash trees over 1.2 inches (3 cm) in diameter were dead within 2 years of first seeing D-shaped EAB exit holes in the stand.

STAND ASSESSMENT CRITERIA

◇ Species Composition

- Canopy, shrub and ground layers
- Potential growth and competition

◇ Regeneration Potential

- Advance regeneration
- Non-ash seed sources
- Other non-ash regeneration sources
- Interfering vegetation
- Deer browse intensity

◇ Stand Structure

- Size class distribution and density
- Age class distribution

◇ Growing stock quality

- Acceptable/Unacceptable Growing Stock
- Vigor
- Degraded vs non-degraded stand condition after ash mortality

◇ Hydrology

- Drainage issues, including drain tile, impediments, terrain and water flow
- Potential rise in water table
- Seedling flood tolerance
- Road impacts and Best Management Practices
- Seasonal inundation period
- Depth to water table
- Soils drainage class and texture

◇ Operational Considerations

- Access
- Volumes
- Seasonal variability
- Economic viability

◇ Landscape-level topography and hydrology

◇ Presence of invasive plants (e.g., reed canary grass, phragmites and buckthorn)

◇ Presence of damaging insects and diseases

Table 1. Stand characteristics used to evaluate management options in stands potentially impacted by emerald ash borer.

Since timber harvests can take several years to complete (particularly in lowland stands), start management activities as soon as practical. This will maximize the amount of time available for management prior to expected heavy ash mortality, and additional silvicultural treatments to establish non-ash regeneration may be feasible. If EAB is already present in or near the stand, immediate management will likely capture more financial value and give a land manager more options for encouraging non-ash regeneration.

It is difficult to accurately predict when EAB will impact a stand in parts of the state where EAB is not yet common. In those areas, infestations are younger and less-established, spread rates are variable, and undetected infestations are likely present. In parts of Wisconsin where EAB is known to be common, EAB is already present in most stands or will soon be present. These stands will likely have fewer management options before EAB impacts them. If ash mortality is already occurring in a stand, active management may be limited to salvage harvests and encouraging the regeneration of non-ash species.

Management Objectives


Timber processor in action, 2010.

Management objectives should be identified within the practices of sustainable forestry. Maintaining forest productivity and improving forest resilience are desirable management goals. Evaluation of factors in the “Stand Assessment” section of this guide will help determine whether active management is practical. Assessment outcomes may result in alteration of management goals, stand entry timelines, or the anticipated stand rotation age. This information may also provide an estimate of financial costs to meet management goals. It may be appropriate to alter an existing management plan if EAB is found in the stand or local area during the lifespan of the plan. Low-quality stands may have to be sold in combination with larger, more valuable stands in order to have active management completed.

RECOMMENDATION: Aim for a species composition (typically less than 20% ash) that would leave a stand adequately stocked and able to meet landowner goals if all remaining ash were harvested or killed by EAB. This objective will usually be easier to meet on an upland site than on a lowland site.

Land managers should be aware that EAB impacts may affect eligibility for the Wisconsin tax law programs. For more information, visit the DNR forestry tax law website. State and federal financial assistance for forest management activities may be available, but is limited.


Black ash stand with flowing water.

Stand Alternatives

Lowland stand in Washington County containing ash and silver maple.

This guide contains several management alternatives based on whether the stand is located in an upland or lowland forest. In general, management in lowland forests is more complicated than in upland forests due to factors such as limited species diversity, site hydrology and invasive plants. Aim for a species composition (typically less than 20% ash) that would leave a stand adequately stocked and able to meet landowner goals if all remaining ash were harvested or killed by EAB. The alternatives are based on the stand/ site-level considerations and whether EAB is known to be present in the stand.

An assessment of degraded or non-degraded stand condition is based on a minimum level of non-ash Acceptable Growing Stock (AGS). The baseline is set at a common threshold of 40 non-ash AGS per acre or approximately 45% relative density (i.e., at the C-line). Stands at or above this baseline should be able to be managed for non-ash species using the appropriate cover type guidance.

Stands below this baseline will be considered degraded after EAB kills the ash component, and may require silvicultural treatments to increase non-ash tree regeneration. However, a forester may need to be flexible when setting a minimum baseline for acceptable stocking. Foresters may decide to manage understocked stands below this baseline (i.e., less than 40 non-ash AGS per acre) if regeneration options are limited.

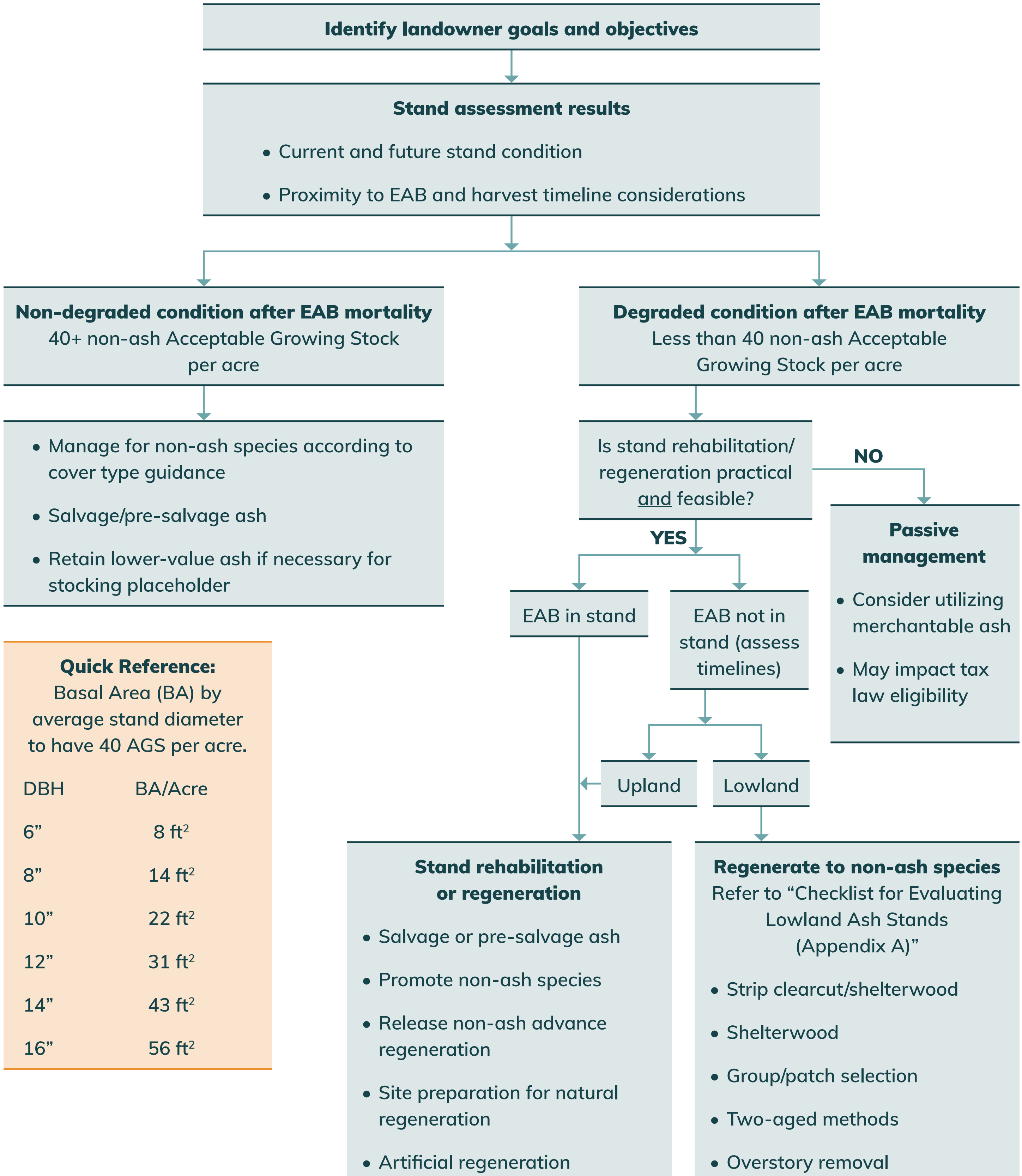
The Stand Management Decision Model (Figure 1) is a tool to aid foresters and land managers in managing ash across many different landscapes in Wisconsin. This model will usually suggest several management options when used in conjunction with the DNR Silviculture Handbook, Checklist for Evaluating Lowland Ash Stands (Appendix A), and Lowland Reforestation Species Guide (Appendix B). It is up to the forester or land manager to make a final management decision. Stand and site conditions and capabilities, management goals, and past successes/failures with ash management on both upland and lowland sites were taken into consideration during model development.

Fall colors in a Washington County northern hardwood stand.

UPLAND STANDS

Upland ash (primarily white ash, although green ash can be found in minor amounts) is generally associated with the northern hardwood cover type, with most stands having less than 20% ash. Other species commonly associated with ash in these stands are sugar maple, basswood, yellow birch and beech, with sugar maple typically being the dominant species. Ash also grows as an associate species in other forest cover types, and only rarely occurs as a dominant component. Upland ash occurs on a wide variety of soil types, but grows best on mesic sites with well-drained to moderately well-drained loamy soils.

STAND MANAGEMENT DECISION MODEL



Quick Reference:
Basal Area (BA) by average stand diameter to have 40 AGS per acre.

DBH	BA/Acre
6"	8 ft^2
8"	14 ft^2
10"	22 ft^2
12"	31 ft^2
14"	43 ft^2
16"	56 ft^2

Figure 1. Stand management decision model. Refer to the upland and lowland sections of these guidelines for more details, and evaluate options carefully.

White ash is generally the fastest growing of all northern hardwood species and often exceeds other associate species in site index by 3-10 feet. It is also a reliable seed producer, with large and abundant seed crops every 3-5 years. For ash that is a component of a northern hardwood stand, consider the silviculture alternatives for this cover type. Follow the stand prescription when selecting trees to remove or retain, keep the stand adequately stocked, and encourage species diversity by promoting non-ash tree species.

Upland forest in Price County.

Upland ash management recommendations are similar whether or not EAB is present. Pre-salvage harvesting will reduce EAB impacts by removing vulnerable trees before they decline and die, and can be used to increase species diversity. Salvage harvesting will capture economic value by harvesting dead or dying trees, although trees may no longer be suitable for sawtimber.

- If pre-salvage or salvage harvesting of ash will not result in a degraded stand (i.e., more than 40 non-ash Acceptable Growing Stock (AGS) per acre remain, or the residual stocking of non-ash trees will be above C-line (approximately 45% relative density)), manage according to cover type silvicultural guidelines and encourage the regeneration of non-ash species in gaps. Monitor and address factors such as invasive plant occurrence and deer browse.
- If pre-salvage or salvage harvesting of ash will result in a degraded stand (i.e., less than 40 non-ash AGS per acre, or non-ash residual stocking will be below C-line (less than 45% relative density)), regenerate the stand to non-ash species according to cover type silvicultural guidelines using natural or artificial methods.

Stand regeneration in a multi-species planting study.

Evaluate how much ash regeneration is desirable and how big stand openings should be to facilitate this regeneration. An ash presence may reduce the growth of invasive plants, but will also be a competitor to non-ash regeneration and its long-term persistence is unknown.

If ash is more than 10% of all regeneration, especially in gaps, consider reducing the ash component with release operations and favor non-ash species. Active treatment of ash regeneration through cutting or herbicide may be needed, especially if ash regeneration is predominant. Supplemental planting of non-ash species is another option to increase the non-ash component. It is recommended that invasive plants be treated prior to EAB impacts, due to the likelihood of increased prevalence as ash die and understory light levels increase. Treatment options can be found in the DNR Silviculture Handbook and at the DNR herbicides for forest management website.

Black ash stand in Sawyer County.

LOWLAND STANDS

Lowland ash (primarily black and green ash) occurs in shallow depressions, floodplains and associated terraces. Sites are seasonally wet, although the water table is almost always close to the surface and reaches the tree rooting zone. Soils can be wet mineral or organic muck over mineral. Other tree and shrub species, such as white cedar, red and silver maple, elm, spruce and alder, can occur depending on the type of lowland stand. Many of these types, however, are predominantly ash with a heavy understory of ash regeneration. Wetland habitat typing is a good indicator of stand characteristics such as quality, site potential and site hydrology.

The establishment of EAB in Wisconsin has increased the importance of finding management strategies to maintain forest productivity and resilience in lowland stands, where silvicultural knowledge has been limited. Important goals will include diversifying overall stand composition and structure. Community responses to EAB are not well-understood, especially in hardwood swamps with few non-ash replacement species (e.g. Slesak et al. 2014; Iverson et al. 2016). Studies have found increased growth in residual non-ash species following the death of ash from EAB (Flower et al. 2013; Burr and McCullough 2014; Costilow et al. 2017).

Intensive site preparation, deer fencing, release treatments and invasive plant control may be required for successful establishment of regeneration. Timber sales can take several years to complete and site access can be unpredictable, so postponing management activities is not recommended. In addition, stand conversion costs will be high without a guarantee of success. Consult a forester to discuss management objectives before any decisions are implemented.

RECOMMENDATION: Since lowland sites may be difficult to successfully manage for emerald ash borer, review available silviculture resources such as the "Checklist for Evaluating Lowland Ash Stands (Appendix A)" and the "Lowland Reforestation Species Guide (Appendix B)."

Guidance for lowland stands is based on silviculture case studies from the Lakes States, the Swamp Hardwood and Bottomland Hardwood chapters of the DNR Silviculture Handbook, the Checklist for Evaluating Lowland Ash Stands (Appendix A), and the Lowland Reforestation Species Guide (Appendix B). The Checklist for Evaluating Lowland Ash Stands (Appendix A) is designed to assist with site and stand evaluation prior to developing a management prescription. The Lowland Reforestation Species Guide (Appendix B) can be used in selecting suitable species for a site and evaluates suitability criteria such as habitat type, soil characteristics, flood tolerance and browse tolerance for each listed species. Due to the complex nature of these sites, it is recommended that the collected data be considered in combination with landowner objectives.

Strip clearcut harvested in winter.

In 2002, DNR staff began collecting detailed information about 29 timber harvests in black ash stands across the state. They have regularly added this information to the DNR silviculture trials database. The trials have indicated stand assessment considerations and regeneration methods that increased species diversity in lowland stands while minimizing site impacts.

In general, lower-intensity treatments such as single-tree selection resulted in less tree regeneration along with lower diversity of non-ash species. Strip shelterwood and strip clearcut trials typically produced more diverse, non-ash regeneration (e.g. red maple, yellow birch, balsam fir and basswood) as long as a seed source was present. Swamping occurred in diameter-limit and clearcut trials, whereas hydrological changes were less dramatic when the strip shelterwood/clearcut and single-tree selection methods were used.

The considerations discussed below should be evaluated before selecting a silvicultural practice to manage these lowland stands. If stand regeneration is not practical or feasible, consider utilizing merchantable ash and letting the stand convert. Alternatively, no active management could be considered. Both of these options may impact tax law program eligibility.

SITE POTENTIAL

Foresters evaluate a lowland site in Outagamie County, 2018.

A careful assessment of site potential will help predict which stands will best respond to management treatments in terms of growth, regeneration and hydrological balance. Intensive management may not be practical in less productive, low-quality stands.

The forest habitat type classification system is commonly used in Wisconsin to assess site capability in both upland and lowland stands. Based on the swamp hardwood trials, wetland habitat types that are slightly richer in nutrients (e.g., FnArl and FnUB in Regions 3 and 4, respectively) seem most capable of supporting higher proportions of non-ash tree regeneration. Post-harvest shrub competition on these sites creates a potential need for follow-up release treatments (Pszwaro et al. 2017). Less-rich habitat types were also found to support moderate-to-high proportions of non-ash tree regeneration with proportionately lower shrub densities, particularly under the strip clearcut and strip shelterwood regeneration methods. Site quality of wetland forests may also be reflected in the depth to mineral soil, as well as influenced by the influx of nutrients from adjacent landforms.

OPERATIONAL CONSIDERATIONS

In ash-dominated lowlands, operational considerations are particularly important due to the seasonally-saturated soil conditions and the generally low value of associated forest products. Foresters should evaluate potential sale volumes relative to local markets when assessing timber sale feasibility. Small stands with difficult access will have limited marketability.

Stands with poor drainage, long seasonal inundation periods and/or deep organic soils may have limited or unpredictable harvest windows, and be more susceptible to site damage. Road systems and other infrastructure can impede water flow and have long-lasting impacts on wetland hydrology and site productivity. Thus, they need to be carefully located and constructed. More information can be found online at the DNR Forestry best management practices website.

Seasonal flooding depths can be seen on the trunk of this ash tree.

REGENERATION POTENTIAL

Maintaining the resilience of ash-dominated lowland stands will require increased non-ash regeneration. Evaluation of regeneration potential should consider factors such as the density and stocking of non-ash advance regeneration, alternate seed sources, browsing pressure, and presence of competing vegetation.

It is recommended that invasive plants be treated prior to EAB impacts, due to the likelihood of increased prevalence when understory light levels increase. Treatment options can be found in the DNR Silviculture Handbook and herbicides for forest management website.

Young tamarack in Washington County.

In lowland silviculture trials, all treatments produced abundant shrub regeneration as well as abundant ash regeneration, due to the ability of ash to easily reproduce from seed and stump sprouts. However, ash regeneration as small as 1" in diameter is susceptible to EAB infestation and cannot be relied on to restock the stand. It is important to note that follow-up release treatments may be necessary to maintain non-ash regeneration over time.

It may be necessary to use a variety of silviculture techniques to maintain adequate forest cover at these sites. Bolton et al. (2018) used mounding techniques, deer repellents and fencing to test a variety of tree species in Michigan and Wisconsin. The study found that silver maple, red maple, American elm and other species were viable replacements for black ash. In addition, planting on natural or artificial hummocks was successful at increasing survival rates of several species. More information about suitable species is available from the DNR silviculture trials website.

HYDROLOGICAL RISK

In these forest systems, it is important to protect hydrological and soil function, and perpetuate the forest canopy so that maximum evapotranspiration can occur. Hydrological risk refers to the potential for "swamping," when a water table rises following harvesting due to tree removal and/or site damage. Assessing hydrological risk should include factors such as length of seasonal inundation, depth to water table, soil characteristics and depth, ease of drainage, likelihood of ponding, and drainage impediments such as beaver dams.

Partial harvest treatments will generally mitigate water table impacts. The risk of impacts is highest for clearcutting and overstory removal treatments, where the primary sources of evapotranspiration (larger trees) are removed in a single operation. However, swamping can also occur with other silvicultural treatments if site factors are high risk, and from impeded drainage due to site damage.

Failed lowland planting in Sawyer County.

Shelterwood post-harvest.

EAB NOT OBSERVED IN THE STAND

In lowland ash stands, there are several silvicultural alternatives that are recommended in the Swamp Hardwood and Bottomland Hardwood Chapters of the DNR Silviculture Handbook, DNR silviculture trials website, and Checklist for Evaluating Lowland Ash Stands (Appendix A).

- **Shelterwood** – This method can help maintain hydrological balance while encouraging non-ash species if alternate seed sources are present. Site preparation for natural regeneration can be difficult on these wet sites, and minimizing competition can be challenging.
- **Strip clearcut/shelterwood** – This method can help maintain hydrological balance and encourage non-ash regeneration if alternate seed sources are present. The harvested strip may be 50 to 200 feet wide, with residual strips harvested at a later date if EAB timelines permit. In lowland systems, this method may also reduce windthrow and improve site access. Deer browse may be heavier in the regenerating areas.

Strip clearcut in Clark County.

- **Group/patch selection** – A group may be 0.1 to 0.5 acre in size, and a patch may be 0.5 to 2.0 acres in size. Group/patch selection encourages the regeneration of mid-tolerant species and has been shown to reduce the risk of swamping. It can also be coupled with site preparation and supplemental, post-harvest planting of non-ash species to increase species diversity.
- **Single-tree selection** – In the past, this method was recommended to encourage and perpetuate black ash. However, recent Wisconsin silviculture trials and other research have indicated that this method is less likely to encourage non-ash regeneration and may not meet management objectives prior to significant EAB mortality. The hydrological balance of the site is likely to be retained.

Tree regeneration in a gap protected by deer fencing.

- **Overstory removal** – This method has been implemented in a few Wisconsin silviculture trials with mixed results. Important considerations include adequate density, size, distribution, and desirable species of non-ash regeneration. This method can increase the risk of swamping and additional planting may be necessary to maintain adequate stocking. One study site had adequate non-ash regeneration, but hydrology was impacted and led to the establishment of cattails and other undesirable vegetation.

- **Clearcut** – Based on silviculture trial results and research studies, clearcutting is not recommended except in limited circumstances. Clearcutting increases the risk of swamping and duration of ponding, and produces a greater abundance of sedge and grass that may compete with establishing seedlings. Both the Wisconsin Silviculture trials and Minnesota research (Slezak et al. 2014; Looney et al. 2015) have found that water tables rise after harvest and initial establishment of tree species is limited.

  One situation where a larger opening may be appropriate is the presence of an aspen component that would successfully regenerate. If the stand is a minimum of 3 acres and contains at least 20 ft^2/acre of uniformly-spaced aspen, consider coppice harvesting to promote aspen regeneration. Harvest boundaries can be extended a tree length away from the nearest aspen to allow for additional sunlight and aspen regeneration opportunities.

A longer timeframe for management may allow residual ash trees to control hydrology and competition until non-ash regeneration becomes established. Encourage the regeneration of non-ash species and/or consider non-ash supplemental planting when evaluating a silvicultural method. The Lowland Reforestation Species Guide (Appendix B) can help select appropriate species to plant.

Green ash stand in Ozaukee County, with canopy decline present.

EAB OBSERVED IN THE STAND

Management options will be more limited in lowland ash stands that are already impacted by EAB. If salvage harvesting of ash will not result in a degraded stand (i.e., more than 40 non-ash Acceptable Growing Stock (AGS) per acre remain, or the residual stocking of non-ash trees will be above C-line (approximately 45% relative density)), manage according to cover type silvicultural guidelines and encourage the regeneration of non-ash species using natural or artificial methods.

Canary grass beneath an ash overstory in Manitowoc County, at a site that will be difficult to actively manage.

If salvage harvesting of ash will result in a degraded stand (i.e., less than 40 non-ash AGS per acre, or non-ash residual stocking will be less than the C-line (less than 45% relative density)), use natural or artificial methods to regenerate the stand to non-ash species if practical and feasible, according to cover type silvicultural guidelines.

Several resources are available to identify options that can potentially rehabilitate degraded lowland ash stands. Resources include the Checklist for Evaluating Lowland Ash Stands (Appendix A) and the Lowland Reforestation Species Guide (Appendix B). In addition, a number of silviculture trials have been conducted on lowland sites throughout the Lakes States.

Disease-resistant elm seedlings selected for planting.

NO ACTIVE MANAGEMENT OPTION

Many ash-dominated lowland sites will be impractical to convert to non-ash tree species because of limited silvicultural options, economic considerations, harvesting impacts, or lack of site access. If stand regeneration is not practical or feasible, consider utilizing merchantable ash prior to passive stand conversion. Mortality from EAB may lead to understocking, conversion to undesirable tree species or non-forest cover, elevated water tables, or an increase in invasive plants such as reed canary grass and phragmites. These outcomes are less likely to occur if active management is selected.

Stands that currently have a predominance of ash may have abundant ash regeneration, but in many cases, regeneration will be poor or non-existent. Either way, this regeneration will become susceptible to EAB as it grows. Bowen and Stevens (2018) predicted that swamps with the least amount of ash will likely experience a proportional increase in non-ash species, whereas the sites with the most ash will likely transition to a shrubby, herbaceous swamp with scattered trees.

Artificial Regeneration

Sycamore planted in a western Wisconsin lowland site.

In many cases, natural regeneration will not be adequate to fully stock a future stand. Planting non-ash species may be the only viable option to reasonably ensure the successful establishment and growth of regeneration. Land managers are encouraged to work with a forester to develop a reforestation plan and estimate financial costs. More information about artificial regeneration techniques can be found in the DNR Silviculture Handbook and DNR Forest Management Guidelines.

SPECIES SELECTION

Species selected for planting must meet management objectives and be suitable for each site. After evaluating the site characteristics, select a mixture of species that emphasize positive traits and overcome limiting factors. Factors that should be considered when selecting species as ash replacements include cover type, habitat type, soil texture and drainage, flood tolerance, shade tolerance, cold hardiness, browse susceptibility, and presence of competing vegetation.

Detailed information about species selection and potential planting methods is available from the Lowland Reforestation Species Guide (Appendix B), the Checklist for Evaluating Lowland Ash Stands (Appendix A), and the DNR silviculture trials website. In general, using larger planting stock has been more successful than using smaller stock. Additional planting techniques are in development. More information can be found the "Additional Resources" section of these guidelines.

SITE PREPARATION

Preparing a site for planting is a critical element of planting success, and is intended to improve growing conditions and control competing vegetation. Site preparation methods vary greatly, depending on the site characteristics and the degree to which competing vegetation interferes with planting. Site preparation treatments can involve chemical and/or mechanical methods. The timing of treatment, herbicide selection, application rates and mechanical treatment methods are all important to success and should be coordinated under the guidance of a forester.

Soil scarification to facilitate natural regeneration.

Upland sites will typically be easier to prepare for planting than lowland sites. Common issues on upland sites include undesirable tree species, competition from grasses and sedges, and control of invasive plants such as honeysuckle, buckthorn and barberry.

Lowland sites will be the most difficult to prepare for tree planting. Undesirable tree species, invasive plants such as reed canary grass, and the seasonally wet nature of these sites can make site preparation challenging. Many sites will only be accessible for site preparation, planting and follow-up maintenance during a few months of the year.

Multiple treatments to prepare a site can quickly become expensive. Making site preparation part of the harvesting activities can keep costs down without discouraging seedling survival. For example, skidding of large trees can expose mineral soil and drop seed. Combining the activities can reduce total expenses, but does require increased planning, an experienced contractor, and development of contract specifications to meet objectives. Reduced timber sale revenue may result, but expenses would also be lower.

PLANTING

Hand planting a site.

Most sites will be hand-planted using a shovel or planting bar since mechanical planting is usually impractical. A rough estimate is that an inexperienced but physically fit person can hand-plant 300 to 500 trees per day. Recommended tree density can vary greatly, but typically will be 500 to 900 trees per acre.

Another option to consider is direct seeding, although very little direct seeding has been done in a forested setting. This cost-effective method can be used where planting is difficult, and can regenerate small areas or quickly reforest large acreage. Use of this method requires a knowledge of species/site combinations and proper seed handling. When compared to planted seedlings, seeded trees often have better root systems and are better suited to their microsites. However, small areas can be more susceptible to seed predation by rodents and deer. Forester assistance is recommended when planning direct seeding.

One disadvantage of direct seeding is a lower success rate, though many of these failures can be attributed to improper planning. Losses of seeds and small seedlings can be high. Hardwood seed is difficult to obtain in most years and does not store well. This uncertainty has led many land managers to select natural regeneration or tree planting instead of direct seeding.

FOLLOW-UP MAINTENANCE

Once trees are planted, it is essential to periodically monitor them and evaluate growth. Typically, plantings will require maintenance and several years of monitoring in order to conclude that establishment was successful. Periodic spraying and/or mowing is recommended to reduce rodent cover, increase the amount of sunlight reaching the trees, and prevent weeds and grasses from smothering the trees until they have grown above the competition.

In addition, protection from deer browsing will often be required to obtain successful results. Many forest sites are now being fenced prior to planting in order to exclude deer. Other methods of browse prevention include bud caps and chemical deterrents. As with site preparation, the methods and timing of treatments, herbicide selection and chemical application rates are all important to success and should be coordinated under the guidance of a forester.

Foresters evaluate a cottonwood and willow planting along the Mississippi River.

Glossary

Acceptable growing stock (AGS)
Live trees of an appropriate species, vigor and form that can be expected to contribute significantly to a future stand as high-quality stems.

Advance regeneration
Seedlings or saplings that are present in the understory in advance of stand rotation.

Basal area
The cross-sectional area of all stems in a stand expressed per unit of land area.

Clearcut
In one operation, the removal of essentially all trees in a stand.

Coppice
A silvicultural method designed to naturally regenerate a stand using vegetative reproduction (sprouts) from stumps or roots.

Direct seeding
Broadcast sowing of tree seeds through aerial or manual means.

Epicormic sprout
A shoot arising from an adventitious or dormant bud on the stem or branch of a woody plant, often following exposure to fire or increased light levels.

Evapotranspiration
The water loss occurring from the processes of evaporation and transpiration from leaves.

Habitat type classification
A site classification system based on the floristic composition of plant communities.

Group/patch selection
The group and patch selection regeneration methods maintain an uneven-aged stand by removing groups/patches of trees at regular intervals. In Wisconsin, these canopy openings are defined as 0.1 to 0.5 acre for group selection and 0.5 to 2.0 acres for patch selection.

Overstory removal
A regeneration method in which a stand's overstory is removed in one entry, to release established seedlings and saplings.

Oxidation staining
Discoloration that occurs following significant exposure to air.

Ponding
The retention of water to form a pond.

Pre-salvage
The harvesting of highly vulnerable trees before they are damaged, decline or die.

Pulpwood
Trees that are between a sapling and a sawtimber tree in size. Typically, these are hardwood trees between 5 and 11 inches in diameter at breast height (dbh), and conifers between 5 and 9 inches dbh.

Quarantine
A system of regulations intended to help prevent the spread of a forest pest or disease, by restricting the movement of articles that could carry that insect or pathogen.

Rehabilitation
The alteration of a stand's species composition and structure to a desired state following degradation such as mortality from emerald ash borer.

Relative density
Stand density expressed as a percentage of the average maximum stocking for stands at a similar stage of development.

Rotation
In even-aged silvicultural systems, the period between regeneration establishment and final cutting. Rotation length may be based on criteria such as growth rate, tree size, age and stand condition.

Salvage
The removal of dead trees, and/or trees that are damaged or dying because of injurious agents other than competition, to recover economic value that would otherwise be lost.

Sawlog
Trees with a minimum diameter, length and stem quality suitable for processing into lumber. Typically, these are hardwood trees larger than 11 inches (dbh) and conifers larger than 9 inches (dbh).

Shelterwood
A regeneration method characterized by multiple cuts, designed to encourage the regeneration of desirable tree species under the shade of residual trees until the residual trees are harvested.

Single-tree selection
A regeneration method to maintain uneven-aged stands by periodically removing individual trees and small groups, creating canopy gaps <0.1 acre in size.

Site index
A species-specific measure of forest productivity (usually for even-aged stands) expressed in terms of the average height of trees included in a specified stand component (dominants, codominants, or the largest and tallest trees) at a specified age.

Site potential
The sum total of all the factors (moisture, nutrients, heat, light, etc.) affecting the capacity of a site to produce forests or other vegetation. Different potentials facilitate growth of some species and limit growth of others.

Site quality
The productive capacity of a site, usually expressed as volume production of a species.

Strip clearcut (aka strip shelterwood)
A regeneration method in which the stand is removed in a series of strips harvested over 2-3 entries, usually covering an equal area on each occasion. The entire removal process is completed within a period of time that does not exceed 20% of the intended rotation interval.

Unacceptable growing stock (UGS)
Live trees that are not expected to significantly contribute to a future stand because they are low vigor, low quality, high risk, or an undesirable species.

Additional Resources

EMERALD ASH BORER

- Wisconsin Emerald Ash Borer Information
- Emerald Ash Borer Information Network

SILVICULTURE INFORMATION

- Checklist for Evaluating Lowland Ash Stands (Appendix A)
- Lowland Reforestation Species Guide (Appendix B)
- DNR Forest Management Guidelines
- DNR Forestry best management practices
- DNR Silviculture Handbook
- DNR silviculture trials directory
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LANDOWNER PROGRAMS AND FINANCIAL INCENTIVES

- DNR Division of Forestry
- DNR forestry assistance locator (DNR and cooperating foresters)
- DNR forest health staff
- DNR tax law and financial assistance programs
- Federal cost share programs
- Wisconsin Invasive Species Council financial assistance directory

FOREST PRODUCTS

- Effects of EAB on wood quality (from Indiana Woodland Steward)
- Wisconsin forest products information

ARTIFICIAL REGENERATION

- Caring for planted trees
- Deer browse prevention
- Herbicides for forest management

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Appendix A: Checklist for Evaluating Lowland Ash Stands (SLIGHTLY REVISED IN 2019)

This checklist/decision tool is for use in lowland ash stands that will potentially be impacted by emerald ash borer (EAB). The checklist is designed to assist with site and stand evaluation prior to developing a prescription. Due to the complex nature of these sites the checklist results should be considered collectively, along with other stand data, landowner objectives, and professional judgment when evaluating management alternatives.

Landowner:

County:

Town:

Section-Town-Range:

Cruiser:

Date:

Compartment:

Stand:

Acres:

SITE QUALITY AND/OR TIMBER SALE OPERABILITY:

Low

- ☐ Wetland FHT - very poor to poor (Habitat Type: __________)
- ☐ SI <40 ft.* (SI Species/Site Index: __________ / __________)
- ☐ Drainage Class - very poorly drained
- ☐ Soil - deep organic/sphagnum bog
- ☐ Vigor - poor tree and stand vigor
- ☐ Sale Volume - limited (e.g., <100 cords or 10 MBF)
- ☐ Sale Access - poor

Medium to High

- ☐ Wetland FHT - poor to rich (Habitat Type: __________)
- ☐ SI >40 ft.* (SI Species/Site Index: __________ / __________)
- ☐ Drainage Class - poorly drained or better
- ☐ Soil - non-sphagnum organic or organic over mineral
- ☐ Vigor - moderate to good tree and stand vigor
- ☐ Growing Stock Quality - acceptable (evaluate AGS)
- ☐ Sale Volume - acceptable (e.g., >100 cords or 10 MBF)
- ☐ Sale Access - fair to good

*It may be difficult to obtain an accurate SI in lowland ash stands. It is not recommended to rely on SI alone for site quality evaluations.

ADVANCE REGENERATION (NON-ASH SPECIES):

Adequate

- ☐ Non-ash, desirable species
- ☐ 2,000+ stems/acre (advance + projected coppice)
- ☐ 2-4 ft. tall
- ☐ Distribution >50% stocking

Present but Inadequate

- ☐ Non-ash, desirable species
- ☐ 200-2,000 stems/acre (advance + projected coppice)
- ☐ 2-4 ft. tall
- ☐ Distribution <50% stocking, grouped

No Potential

- ☐ Mostly ash or undesirable species
- ☐ <200 stems per acre (advance + projected coppice)
- ☐ <2 ft. tall (e.g., 1st year germinants)
- ☐ Distribution - limited

POTENTIAL EAB IMPACT TO STAND CONDITION:

Non-Degraded

- ☐ ≥40 non-ash AGS (Acceptable Growing Stock) trees per acre or >45% relative density of non-ash AGS

Degraded

- ☐ <40 non-ash AGS trees per acre or <45% relative density of non-ash AGS

ALTERNATE SEED SOURCES:

Good

- ☐ 5-10+ non-ash AGS/seed trees per acre
- ☐ Dominant or codominant crown class
- ☐ Reproductively mature
- ☐ Dispersed

Poor

- ☐ <5 non-ash AGS/seed trees per acre
- ☐ Intermediate and suppressed crown classes
- ☐ Reproductively immature
- ☐ Poorly distributed

HERBIVORY:

Low

- ☐ Browse severity index 1-3

High

- ☐ Browse severity index 4-6

STAND COMMENTS:

HYDROLOGICAL RISK:

Low

- ☐ Seasonal inundation of limited duration (<60 days)
- ☐ Depth to water table >12 in. during majority of growing season
- ☐ Ponding infrequent
- ☐ Drainage Class - poorly drained or better, convex surfaces
- ☐ Shallow organic or mineral soils
- ☐ Limited impediments to drainage

High

- ☐ Seasonal inundation common, well into growing season (>60 days)
- ☐ Depth to water table <12 in. during majority of growing season
- ☐ Ponding frequent
- ☐ Drainage Class - very poorly drained, concave surfaces, limited water flow
- ☐ Deep organic soils/sphagnum bog
- ☐ Impeded drainage due to roads, culverts, other impounding factors

INTERFERING VEGETATION:

Low

- ☐ <25% coverage
  Reed canary grass, buckthorn, alder, other __________

High

- ☐ ≥25% coverage
  Reed canary grass, buckthorn, alder, other __________

Site Quality/Operability	EAB Stand Impact	Hydrological Risk	Advance Regeneration	Alternate Seed Sources	Herbivory	Interfering Vegetation	Prescription Alternatives
Low	n/a	n/a	n/a	n/a	n/a	n/a	Limited Management Potential - Low priority stand, potential for non-timber management objectives (e.g., wildlife habitat)
Medium-High	Not Degraded	n/a	n/a	n/a	n/a	n/a	Alternative Cover Type - Manage for non-ash species according to appropriate cover type guidance
Medium-High	Degraded	Low	Adequate	n/a	n/a	n/a	OSR, TA
Medium-High	Degraded	Low	Present but Inadequate	Good	Low	Low	OSR (advance regen. sufficient), SCC, SW, GPS, P-O, R-O
Medium-High	Degraded	Low	Present but Inadequate	Good	Low	High	OSR (advance regen. sufficient), SCC, SW, GPS, P-O, R-R
Medium-High	Degraded	Low	Present but Inadequate	Good	High	Low	OSR (advance regen. sufficient), SCC, SW, GPS, P-O, R-O, BP
Medium-High	Degraded	Low	Present but Inadequate	Good	High	High	OSR (advance regen. sufficient), SCC, SW, GPS, P-O, R-R, BP
Medium-High	Degraded	Low	Present but Inadequate	Poor	Low	Low	OSR (advance regen. sufficient), SCC, GPS, P-R, R-O
Medium-High	Degraded	Low	Present but Inadequate	Poor	Low	High	OSR (advance regen. sufficient), SCC, GPS, P-R, R-R
Medium-High	Degraded	Low	Present but Inadequate	Poor	High	Low	OSR (advance regen. sufficient), SCC, GPS, P-R, R-O, BP
Medium-High	Degraded	Low	Present but Inadequate	Poor	High	High	OSR (advance regen. sufficient), SCC, GPS, P-R, R-R, BP
Medium-High	Degraded	Low	No Potential	Good	Low	Low	SCC, SW, GPS, P-R, SP-O
Medium-High	Degraded	Low	No Potential	Good	Low	High	SCC, SW, GPS, P-R, SP-R
Medium-High	Degraded	Low	No Potential	Good	High	Low	SCC, SW, GPS, P-R, SP-O, BP
Medium-High	Degraded	Low	No Potential	Good	High	High	SCC, SW, GPS, P-R, SP-R, BP
Medium-High	Degraded	Low	No Potential	Poor	Low	Low	SCC, GPS, P-R, SP-O
Medium-High	Degraded	Low	No Potential	Poor	Low	High	SCC, GPS, P-R, SP-R
Medium-High	Degraded	Low	No Potential	Poor	High	Low	SCC, GPS, P-R, SP-O, BP
Medium-High	Degraded	Low	No Potential	Poor	High	High	SCC, GPS, P-R, SP-R, BP
Medium-High	Degraded	High	Adequate	n/a	n/a	n/a	SCC, GPS
Medium-High	Degraded	High	Present but Inadequate	Good	Low	Low	SCC, GPS, P-O, R-O
Medium-High	Degraded	High	Present but Inadequate	Good	Low	High	SCC, GPS, P-O, R-R
Medium-High	Degraded	High	Present but Inadequate	Good	High	Low	SCC, GPS, P-O, R-O, BP
Medium-High	Degraded	High	Present but Inadequate	Good	High	High	SCC, GPS, P-O, R-R, BP
Medium-High	Degraded	High	Present but Inadequate	Poor	Low	Low	SCC, GPS, P-R, R-O
Medium-High	Degraded	High	Present but Inadequate	Poor	Low	High	SCC, GPS, P-R, R-R
Medium-High	Degraded	High	Present but Inadequate	Poor	High	Low	SCC, GPS, P-R, R-O, BP
Medium-High	Degraded	High	Present but Inadequate	Poor	High	High	SCC, GPS, P-R, R-R, BP
Medium-High	Degraded	High	No Potential	Good	Low	Low	SCC, GPS, P-R, SP-O
Medium-High	Degraded	High	No Potential	Good	Low	High	SCC, GPS, P-R, SP-R
Medium-High	Degraded	High	No Potential	Good	High	Low	SCC, GPS, P-R, SP-O, BP
Medium-High	Degraded	High	No Potential	Good	High	High	SCC, GPS, P-R, SP-R, BP
Medium-High	Degraded	High	No Potential	Poor	Low	Low	SCC, GPS, P-R, SP-O
Medium-High	Degraded	High	No Potential	Poor	Low	High	SCC, GPS, P-R, SP-R
Medium-High	Degraded	High	No Potential	Poor	High	Low	SCC, GPS, P-R, SP-O, BP
Medium-High	Degraded	High	No Potential	Poor	High	High	SCC, GPS, P-R, SP-R, BP

Key to Prescription Alternatives:
Overstory Removal (**OSR**)
Strip Clearcut/Coppice (**SCC**)
Two-Age (**TA**)
Shelterwood (**SW**)
Group/Patch Selection (**GPS**)
Supplemental Planting – Optional (**P-O**)
Supplemental Planting – Recommended (**P-R**)
Release – Optional (**R-O**)
Release – Recommended (**R-R**)
Site Preparation for Natural Regeneration – Optional (**SP-O**)
Site Preparation for Natural Regeneration – Recommended (**SP-R**)
Browse Protection (**BP**)

Developing Silvicultural Prescription Alternatives for Lowland Ash Stands:

The following guidance is based on current research and silvicultural case studies from the Lake States, and is specifically directed at ash-dominated lowlands that will be heavily impacted by EAB. These lowland stands are found in both the swamp hardwood and bottomland hardwood cover types, where the primary tree species may include black ash, green ash, red maple, silver maple, swamp white oak and elm. Current silvicultural guidelines for the regeneration of these cover types is tentative and incomplete, due in part to limited knowledge and experience managing these complex ecosystems for species other than ash. The threat of EAB has increased the urgency to find management strategies that maintain forest productivity and improve forest resilience. This guidance will highlight some of the important stand assessment considerations and regeneration methods that have shown the most promise for increasing species diversity in lowland ash stands. Many of these recommendations are based on lessons learned from a series of 29 swamp hardwood silvicultural trials conducted over the past 40 years in Wisconsin, and draws from other emerging research in the Lake States. Additional management information can be found in the Swamp Hardwood and Bottomland Hardwood chapters of the Silviculture Handbook.

STAND ASSESSMENT CONSIDERATIONS

Proximity to EAB Infestations: An important consideration affecting the choice of silvicultural alternatives for an ash stand is the proximity to known EAB infestations, and thus, the amount of time available for management prior to major ash mortality. EAB was first detected in Wisconsin in 2008 and has now been found in most of the 72 Wisconsin counties. Once EAB is detected in an area it may take several more years for the population to build to a level that will cause significant tree mortality. A study using FIA and county-level quarantine data found this lag time to be 7-10 years (Morin et al. 2016). EAB may be present in an area for several years prior to detection, so the actual lag time between establishment and mortality is likely greater. If mortality is already occurring in a stand, management options may be limited to salvage operations. A management window of several years or longer, however, will allow for more flexibility, such as the use of alternative regeneration methods and/or multiple stand entries. The goal should not be to remove all ash in every situation, without first carefully considering management timeframes and site opportunities to improve future stand conditions.

Site Quality/Wetland Forest Habitat Type: A careful assessment of site quality will help prioritize which stands will best respond to management treatments in terms of growth, regeneration and hydrology. Low-quality sites, as defined within the checklist, generally have lower productivity and it may not be practical to invest in extensive management treatments. The Forest Habitat Type Classification System has commonly been used in Wisconsin to assess upland site capability based on the floristic composition of plant communities, and now that system has been extended to wetland forests in northern Wisconsin. Based on the swamp hardwood trials, habitat types that are slightly richer in nutrients (e.g., FNArl and FnUb in Regions 3 and 4, respectively) seem most capable of supporting higher proportions of non-ash tree regeneration. Post-harvest shrub competition on these sites is proportionately higher, creating the potential need for follow-up release treatments (Pszwaro et al. 2016). Less-rich habitat types were also found to support moderate-to-high proportions of non-ash tree regeneration with proportionately lower shrub densities, particularly under the strip clearcut and strip shelterwood regeneration methods. Site quality of wetland forests may also be reflected in the depth to mineral soil, as well as influenced by the influx of nutrients from adjacent landforms.

Timber Sale Operability: Sale operability considerations are particularly important in ash-dominated lowlands, due to both the seasonally-saturated soil conditions and the generally low value of associated forest products. Stands with very poor drainage classes, long seasonal inundation periods, deep organic soils, and/or impeded drainage may have limited harvest windows and be more susceptible to site damage due to rutting and swamping. Harvesting during frozen conditions, using logging mats, and driving over tops/branches can minimize site damage. Road systems and other infrastructure can have long-lasting impacts on wetland hydrology and site productivity by impeding water flow, and therefore need to be carefully located and constructed. Foresters should also evaluate potential sale volumes relative to local markets when assessing timber sale feasibility. Small stands with difficult access will have limited marketability, and may forgo active management or need to be sold in combination with adjacent, upland stands.

Hydrological Risk: Hydrological risk refers to the risk of “swamping,” where water tables rise post-harvest due to tree removal and/or site damage. The risk is considered greatest for clearcutting and overstory removal treatments where all larger trees (the main sources of evapotranspiration) are removed in a single operation, but swamping can occur with other silvicultural treatments as well if site factors are high risk. Swamping was noted in three of the 29 swamp hardwood trials: a clearcut, a 120’ strip clearcut/coppice harvest and a diameter-limit harvest. Swamping can lead to tree regeneration delays, failures, and shifts in the vegetation to obligate wetland species such as alder and grasses/sedges. A water table response study in Minnesota black ash wetlands found water level increases to be greatest in simulated EAB mortality (i.e., girdling down to 4” DBH) and clearcutting treatments, and lowest in group selection treatments (Slesak et al. 2014). Partial harvest treatments will generally mitigate the water table impacts by maintaining tree canopy. Predicting the risk of swamping is difficult, however, and will vary depending on site hydrology, annual precipitation, and the period of time necessary to re-establish vegetation (Slesak et al. 2014). The checklist provides a partial list of factors to consider when assessing site hydrology and swamping risk. Also consider the landscape context of the wetland forest being managed. Larger watershed issues, such as major road impoundments or beaver dams, may impact hydrology over extensive areas.

Potential EAB Impacts to Stand Condition: The checklist provides an assessment of degraded versus non-degraded stand condition based on a minimum level of non-ash AGS (Acceptable Growing Stock). The baseline is set at 40 non-ash AGS per acre or approximately 45% relative density. Stands at or above this baseline should be able to be managed for non-ash species according to the appropriate cover type guidance. Stands below this baseline will be considered degraded after EAB kills the ash component and may require silvicultural treatments to increase non-ash tree regeneration. Foresters may decide to continue to manage understocked stands below this baseline (i.e., <40 non-ash AGS per acre) if regeneration options are limited.

Regeneration Potential: Maintaining the resilience of ash-dominated lowland stands in the face of EAB will require increasing tree diversity, specifically increasing non-ash tree regeneration. The checklist assesses the non-ash regeneration potential of a stand by evaluating several factors: non-ash advance regeneration density and stocking, alternate seed sources, herbivory pressure and interfering vegetation. In the silvicultural trials, all treatments produced abundant ash regeneration due to the ability of ash to easily reproduce from seed and stump sprouts. Ash regeneration as small as 1” DBH, however, is susceptible to EAB infestation and cannot be relied on as a viable species to restock the stand. Evaluating the regeneration potential of alternate species will help in the selection of prescription alternatives geared towards increasing the non-ash tree component. However, the initial abundance of ash and shrub regeneration following all treatments in the silviculture trials suggests follow-up release treatments may be necessary to maintain the non-ash regeneration over time.

Landowner Objectives: All silvicultural prescriptions must be considered within the context of compatible landowner objectives. Defining a landowner’s objectives becomes even more critical for ash-dominated lowlands because of the challenges and potential costs associated with managing these systems. A significant investment may be needed to implement some of the management treatments described below. Foresters can help landowners prioritize where to make these investments in management through careful stand assessments, using tools such as the checklist. Prioritization may be based on multiple considerations such as stand size, accessibility, ecological importance, probability of treatment success, impacts to hydrology, and several other factors discussed here. Many ash-dominated lowland stands will have limited options and EAB mortality will be allowed to run its course. Other stands will have greater opportunities, and silvicultural treatments can be used to build resilience to EAB impacts, improve future stand productivity, and utilize the ash resource that is being lost.

REGENERATION METHODS

Overstory Removal (aka Natural or One-Cut Shelterwood): An overstory removal is a regeneration method in which the stand overstory is removed in one cut to provide release of established seedlings and saplings. Important considerations when using this method include having adequate density, distribution, height, vigor, and desirability of established non-ash advance regeneration. Overstory removal is a generally-accepted practice in the swamp hardwood and bottomland hardwood cover types as long as density and stocking are maintained with at least 2-5,000 well-distributed trees per acre and trees that are 2-4' in height. This advance regeneration needs to be desirable non-ash species in order to avoid understocking the stand once EAB kills the ash component. Because the entire overstory is being removed in one cut there may be a risk of swamping, so this method may be best on low-risk sites. If the advance regeneration is well-established and deep rooted, there are some indications that rapid re-vegetation of a site can mitigate some of the water table rise (Slesak et al. 2014). Swamping risk may be mitigated through patch or strip overstory removals that retain a portion of the forest canopy.

Strip Clearcut/Coppice (aka Strip Shelterwood): In a progressive strip clearcut/coppice the stand is removed in a series of strips harvested over 2-3 entries, usually covering an equal area on each occasion. The entire stand-level strip removal process is completed within a period of time not exceeding 20% of the intended rotation. In lowland stands, this method may be chosen to reduce the risk of swamping and windthrow, as well as improve equipment operability. The mode of regeneration in ash-dominated lowland stands is often from both seed and coppice. In Wisconsin, these strips have generally been 50'-200' in width and remove approximately 1/3 to 1/2 of the stand at each entry. This method may also be defined as a strip shelterwood, as narrow strips (i.e., 120' or less) will have growing conditions that are significantly modified by the adjacent uncut strips. The strips are often oriented at right angles to the prevailing winds in order to aid in seed dispersal. In the swamp hardwood trials, strip clearcut/coppice generally provided the best balance between establishing regeneration (including a high proportion of non-ash species) and maintaining site hydrology.

Shelterwood (Uniform): The shelterwood regeneration method is designed to regenerate a stand by manipulating the overstory and understory to create conditions favorable for the establishment and survival of desirable tree species. The overstory serves to modify understory conditions, create a favorable environment for reproduction, and provide a seed source. The method is characterized by a preparatory cut (optional), seeding cut(s) and overstory removal. The variation of strip shelterwood was discussed above. Uniform shelterwood, where the residual trees are uniformly distributed, has also been utilized in both swamp hardwood and bottomland hardwood stands to encourage more mid-tolerant species such as yellow birch, red maple, silver maple, swamp white oak and white pine. Successful application of this method is often tied to creating proper seedbed conditions and timing relative to the production of good seed crops. Site preparation for natural regeneration on these sites can be difficult due to the wet conditions and further development of interfering vegetation. Promising chemical site preparation treatments have been demonstrated in bottomland hardwood stands with a late fall application of pre-emergent herbicides to control reed canary grass, allowing for a window of seedbed exposure (Thomsen et al. 2012). The seeding cut should generally leave a uniform 50-75% crown cover of vigorous dominant and co-dominant trees, favoring non-ash seed sources. Uniform shelterwood may be most applicable on medium- to high-quality sites with better drainage, where improved equipment operability allows access throughout the stand.

Group/Patch Selection: The group and patch selection methods maintain an uneven-aged stand by removing groups/patches of trees at regular intervals. In Wisconsin these canopy openings are defined as 0.1 to 0.5 acre for group selection and 0.5 to 2.0 acres for patch selection. These methods are appropriate for encouraging many mid-tolerant species and the retention of a partial canopy may help mitigate swamping risk. Consideration needs to be given to the percentage of the stand regenerated at each entry, given the likely short timeframe until EAB infestation. There may not be enough time available for multiple entries prior to significant EAB-caused mortality. In the swamp hardwood trials, regeneration response was most limited for low-intensity treatments (i.e., single-tree and group selection), resulting in the lowest seedling densities. Aggressive patch selection could be used to speed the regeneration process by harvesting larger areas of the stand. However, consideration will need to be given to increased swamping risk and further development of interfering vegetation. Group and patch selection have been successfully coupled with site preparation and supplemental planting in order to increase species diversity in stands with limited alternate seed sources. A Minnesota study found that trees planted within group selection openings had better overall survival than in clearcuts, suggesting that group selection may be a good compromise for maintaining site hydrology while supporting seedling development (Looney et al. 2015).

Two-Aged Methods: Broadly speaking, two-aged methods retain scattered trees or groups of trees following a harvest (i.e., standards or reserves) while initiating a new age class. The result is a stand of trees with two distinct age classes, separated in age by more than 20% of the rotation interval. Trees can be retained for several reasons, including additional growth, wildlife habitat, aesthetics, or as an alternate seed source to slowly convert a stand to a different composition. Coppice with standards has been the most common two-aged method applied to Wisconsin lowland ash stands. When applied to black ash swamps this regeneration method is designed to naturally regenerate the stand using vegetative reproduction from stump sprouts, while retaining standards or reserve trees of a desirable seed source (e.g., yellow birch, red maple, silver maple, white pine, white spruce, tamarack and cedar) to maintain site hydrology and promote the conversion to alternate species. Depending on the degree of canopy removal, this method can present a swamping risk and may therefore be best on low-risk sites. Retained trees will be more susceptible to windthrow due to the shallow rooting zone and wet soil conditions. In ash-dominated lowlands, significant coppice ash reproduction should be expected.

Impacts of Clearcutting: Clearcutting, or the removal of most or all woody vegetation during a harvest leading to natural regeneration from seed, is not a generally-accepted practice in swamp hardwoods or bottomland hardwoods, primarily due to the removal of most seed sources and the risk of swamping. In the swamp hardwood trials, clearcutting generally produced the lowest density of non-ash tree regeneration and the highest shrub density. Slesak (2014) found that clearcutting black ash stands resulted in a significant water table rise, compared to group selection and control treatments. Clearcutting has also been found to lead to a greater abundance of sedges, grasses, and shrubs that may necessitate vegetation control treatments to establish artificial regeneration (Looney et al. 2017). Given these risks, other regeneration methods are recommended if EAB has not yet infested the stand or if alternative tree species are available to manage. Once EAB-caused mortality has begun in an ash-dominated stand, there may be few options other than salvage harvesting/clearcutting and artificial regeneration.

INTERMEDIATE TREATMENTS

Release: The swamp hardwood trials found a strong regeneration response from ash and shrub species across all habitat types and prescriptions, suggesting that follow-up release treatments may be necessary to maintain non-ash regeneration over time. In particular, ash stump sprouts demonstrate rapid juvenile growth and may quickly overtop other regeneration if not controlled. EAB-caused mortality may help release other species over time, but regenerating stands should be monitored for release needs.

Site Preparation for Natural Regeneration: Proper seedbed conditions are necessary to encourage natural regeneration in some treatments, especially for species preferring an exposed humus or mineral soil (e.g., yellow birch, red maple, silver maple, swamp white oak, tamarack and white pine). Site preparation for natural regeneration can be accomplished via mechanical or chemical methods, prescribed burning, or a combination of these techniques. Site preparation may be difficult on these sites due to swamping, rutting potential, and further development of interfering vegetation. Promising chemical site preparation treatments have been demonstrated in bottomland hardwood stands with a late fall application of pre-emergent herbicides to control reed canary grass, allowing for a window of seedbed exposure (Thomsen et al. 2012). The checklist defines low levels of interfering vegetation as less than 25% coverage, where site preparation treatments may be optional depending on the aggressiveness of the existing interfering vegetation and the seedbed requirements. Site preparation treatments may be required if high levels of interfering vegetation (i.e., ≥25% coverage) are present, but the vegetation should be further evaluated in terms of percent coverage, species, light levels and seedbed requirements.

Thinning: Thinning is often difficult on wet sites due to equipment operability concerns and economic limitations. In ash-dominated stands, it may be prudent to initiate regeneration treatments rather than thinning, given the relatively rapid spread of EAB in Wisconsin. Thinning resulted in low regeneration densities in the swamp hardwood trials, as with other low-intensity treatments. In mixed stands, thinning may be more appropriate to increase the proportion of non-ash species, while utilizing the ash resource. Stands at or above 40 non-ash AGS per acre (or 45% relative density) may be suitable for thinning treatments using the alternative cover type guidance.

Impacts of Diameter-Limit Cutting: Diameter-limit cutting is sometimes proposed for the pre-salvage of ash-dominated lowland stands as a way to harvest the greatest economic value prior to EAB-caused mortality. This cutting practice, however, may have unintended negative consequences on future productivity and resilience in lowland stands. Slesak (2014) found that water tables rose the most in simulated EAB mortality treatments that girdled trees down to 4" DBH, similar to how a diameter-limit treatment would retain only smaller diameter classes. This response was attributed to reduced transpiration, coupled with the presence of a partial canopy that reduced vegetation establishment. Leaving a partial canopy of unacceptable growing stock may inhibit the development of desired tree regeneration. Decades of experience with diameter-limit cutting in other forest types has shown that this practice degrades overall stand conditions and is a largely haphazard approach to regenerating forest systems (Nyland 2005).

ARTIFICIAL REGENERATION

Supplemental Planting: Artificial regeneration is an option to maintain forest cover in ash-dominated stands with poor natural regeneration potential. Due in part to the difficulty and expense of reforesting entire lowland stands, tree planting is more often used to supplement natural regeneration methods. Supplemental or enrichment planting requires a careful evaluation of existing advance regeneration (including potential coppice reproduction), interfering vegetation, and species and stock type selection. Seedlings can be planted within harvest openings or underplanted below existing ash stands in anticipation of EAB mortality. Large bareroot or containerized seedlings are usually needed to compete with the advance regeneration and interfering vegetation, as well as to survive periods of water inundation on wet sites. In Wisconsin, foresters have experimented with fall planting in order to avoid spring inundation periods that can last until mid-summer. Survival can be improved by planting seedlings on drier microsites and avoiding wet depressions. Interfering vegetation from both native and invasive species can be particularly severe on lowland sites, so site preparation is often required to ensure the survival of planted stock. Deer browse may also have significant impacts on planted seedlings and can make those seedlings less able to survive long periods of flooding (De Jager et al. 2013). Follow-up release is often required, as planted stock typically lags behind natural regeneration in height growth.

Reforestation experience is limited in lowland forests of the Lake States. A 2010 swamp hardwood trial in Sawyer County attempted reforestation of a former tag alder and black ash swamp using a variety of bareroot and containerized stock, including tamarack, white pine, white spruce, black ash, yellow birch, red maple, quaking aspen, hemlock and balsam fir. Survival and growth of the conifers was superior to deciduous species, with tamarack and white pine performing best. Deer browse impacted the deciduous seedlings most, yet some yellow birch seedlings showed exceptional height growth. A 2013 American elm reforestation trial in Minnesota, Wisconsin and Iowa planted elm and swamp white oak seedlings on a variety of bottomland hardwood sites ranging from former fields to clearcut and group selection openings. Survival of the 1-0 bareroot stock was generally excellent after two growing seasons. However, height growth was poor with deer browse evident on more than 75% of elm seedlings across all sites. Prolonged water inundation and interfering vegetation were limiting factors on some sites (Haugen et al. 2016). A larger-scale American elm underplanting trial was started on the Avon Bottoms Wildlife Area in Rock County in 2014, but the results have not yet been reported. A 2011 study in Minnesota black ash swamps planted a variety of bareroot and containerized stock (i.e., yellow birch, balsam poplar, tamarack, black spruce, eastern cottonwood, quaking aspen, white cedar, basswood, red maple, American elm, hackberry, swamp white oak and Manchurian ash) within clearcut, group selection, girdling and control treatments (Looney et al. 2015). This study found that trees planted within group selection openings had better overall survival than in clearcuts, suggesting that group selection may be a good compromise for maintaining site hydrology while supporting seedling development. Mortality was generally high, with the majority of species having less than 50% survival in the first growing season. The best performing species were Manchurian ash, swamp white oak, American elm and hackberry – all of which were large bareroot stock. Conifer survival was poor in this study. Fall planting was preferred over spring planting due to improved accessibility, but survival results were mixed between spring- and fall-planted seedlings, depending on species and overstory treatment. A pair of artificial regeneration studies in black ash wetlands on the Ottawa National Forest and Superior Municipal Forest planted a variety of species with a focus on using natural and constructed hummock microsites (i.e., mounding) (Bolton et al. 2016). Trees planted on both natural and constructed hummocks had better survival, with American elm, silver maple, white cedar and red maple performing the best.

Species and Stock Selection: Species and stock selection are critically important for successful tree planting, especially in lowland stands where there are a limited number of adapted species to choose from and overall growing conditions can be challenging. The selected tree species must be compatible with the landowner's management goals and biologically suited to the planting site. Non-ash species considered for reforestation of bottomland and swamp hardwood stands in Wisconsin have included silver maple, red maple, river birch, yellow birch, paper birch, swamp white oak, bur oak, American elm, cottonwood, quaking aspen, hackberry, basswood, tamarack, white cedar, black spruce, hemlock and white pine. Species from this list that have generally shown the best survival and growth in local studies and field trials have included silver maple, yellow birch, swamp white oak, American elm, cottonwood, tamarack, black spruce and white pine. Additional non-local species successfully tested on lowland sites in southern Wisconsin have included American sycamore and Kentucky coffeetree. A controlled flooding experiment testing the flood tolerance of planted seedlings found that swamp white oak and eastern cottonwood maintained the best growth and vigor over prolonged periods of water inundation (Kabrick et al. 2011). The Swamp Hardwood chapter of the Silviculture Handbook includes an analysis of local species that were historically present in public land swamp hardwood stands, based on data from the Public Land Survey of the mid-1800s. At many locations in northern Wisconsin, it appears that the representation of conifers, particularly white cedar and tamarack, in these stands is much lower now than it was historically. Seed source is also an important consideration to ensure climatic suitability and long-term stand productivity. Climate change will complicate the determination of appropriate seed sources due to potential shifts in suitable habitat. Some studies have experimented with the use of seed sources from southerly locations, although at this time there is limited seed movement guidance for most lowland species. In Wisconsin, hardwood seed sources have generally been considered suitable if they are from no more than 100-150 miles south of the planting site. Other tree species, such as American elm, have their own forest health challenges. At this time there are no tested American elm seed sources that are both Dutch elm disease-resistant and appropriate for wide-scale reforestation based on provenance suitability. Research and field trials continue in this area.

Stock selection includes both the propagation method (i.e., bareroot, containerized, cuttings) and plant size (e.g., stock age class, container size, cutting size). All of the propagation methods may be appropriate for lowland sites, depending on the species and planting method. Larger stock size has generally been favored for better survival on lowland sites due to high levels of interfering vegetation and periods of water inundation. Seedlings with portions of the stem remaining above water during periods of flooding have been observed to have better survival rates. Large containerized stock is expensive, but generally demonstrates high survival rates and superior initial height growth. Bareroot stock is lower-cost, generally easier to transport, and can have a competitive advantage over weeds. The American elm trial cited above observed that younger 1-0 elm stock had a better root-to-shoot balance and grew exceptionally well if not damaged by browse. Further trials are needed to help refine species and stock selection guidelines for lowland stands.

Browse Protection: Deer browse is often a significant barrier to successful tree planting in lowland stands. Small-scale plantings, such as those within group and patch selection openings, can be particularly susceptible. Nursery-grown stock is also considered more susceptible to browse due to higher plant nutrient concentrations. If browse is expected to be a limiting factor, consider applying browse protection measures. Options include both physical barriers (e.g., tree shelters, bud caps, fencing, tree tops) and repellents. In areas with severe browse pressure, many foresters have been experimenting with polypropylene fencing around harvest gaps and patches. Costs for this fence are currently running around $1-2 per linear foot. Lowland stands with moving flood waters may present fence maintenance challenges.

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Note: Development of this checklist was led by Greg Edge (Wisconsin DNR), with input from Colleen Matula (Wisconsin DNR), Brad Hutnik (Wisconsin DNR), Bill Ruff (Wisconsin DNR), Anthony D'Amato (University of Vermont), and Justin Pszwaro (The Nature Conservancy). Work contributing to the development of this checklist was supported by funding through the USDA Forest Service Northeastern Area State and Private Forestry, the Department of Interior Northeast Climate Science Center, the Upper Midwest and Great Lakes Landscape Conservation Cooperative, and the Wisconsin Department of Natural Resources.

Appendix B: Lowland Reforestation Species Guide (SLIGHTLY REVISED IN 2019)

	Species	Cover Type Suitability Rating: SH - North	SH - South	BH - North	BH - South	Climate Change Class: Northern WI	Southern WI	Driftless Area	Northern Wetland Forest Habitat Type: PmLLe	PmLLe-An	PmLNe	PArGy	Larlx	AbThArAsp	AbFnThOs	AbFnThlx	ArFnRh	ThAbFnC	ThAbFnlx	FNOn	FnAbl	FnArl-lx	FnAbArOn	FnUB	Soil: Mineral	Organic	Soil Drainage Class: Excessively	Somewhat excessively	Well	Moderately well	Somewhat poorly	Poorly	Very poorly	Seedling Flood Tolerance	Shade Tolerance	Browse Preference	Interfering Vegetation	Insect/Disease Considerations	Planting Considerations
Native Deciduous	*Acer negundo* (boxelder)	◐	●	◐	●	▲	▲	▲														■		■	■	■			■	■	■	■	□	▶	▶	▼	▶		Limited stock availability. If available, 1-0 stock acceptable. Considered interfering vegetation on some sites, particularly old field plantings.
	Acer nigrum (black maple)	○	○	○	◐	▶	▶	▶																	■				■	■	■	□		▼	▲	▶	▶	Presumed to be the same as *A. saccharum*, but mature trees are less susceptible to mortality from flooding.	Limited stock availability. Large 2-0 or 3-0 stock.
	Acer rubrum (red maple)	●	●	●	●	▶	▶	▼	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	□	▶	▲	▶	▲	**Mature:** susceptible to mechanical damage.	Large bareroot 2-0 or 3-0 stock.
	Acer saccharum (sugar maple)	◐	○	○	○	▶	▶	▶						■	■					■	■	■	■		■				■	■	■	□		▼	▲	▲	▶	**Immature:** consumption of duff layer by invasive worms prevents successful establishment; sugar maple borer. **Mature:** susceptible to soil compaction, drought, multiple factor-induced decline.	Large bareroot 2-0 or 3-0 stock. Requires better drained microsites.
	Acer saccharinum (silver maple)	◐	●	●	●	▲	▲	▲						■										■	■	■			■	■	■	■	■	▲	▶	▲	▼	**Mature:** susceptible to ice damage, windthrow. Staining from Columbian timber beetle can reduce wood value.	Standard bareroot 1-0 or 2-0 stock. Potential for direct seeding.
	Betula alleghaniensis (yellow birch)	◐	○	◐	○	▼	▼	▼	■		■		■	■	■			■	■	■	■		■		■	□			■	■	■	□		▶	▶	▲	▶	**Mature:** susceptible to windthrow, bronze birch borer, multiple factor-induced decline.	Large bareroot 2-0 or 3-0 stock.
	Betula nigra (river birch)	◐	◐	●	●	▲	▲	▲																	■	■			■	■	■	■	■	▶	▼	▼	▼		Standard bareroot 1-0 or 2-0 stock.
	Betula papyrifera (paper birch)	◐	○	◐	○	▼	▼	▼	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	□	□	■	■	■	■	■	□	▶	▼	▲	▼	**Mature:** drought/heat stress makes paper birch susceptible to mortality from bronze birch borer.	Standard bareroot 1-0 or 2-0 stock. Potential for direct seeding.
	Carpinus caroliniana (musclewood)	●	●	●	●	▲	▶	▶									■			■					■	■		□	■	■	■	■		▶	▼	▼	▼		Limited stock availability. Large bareroot 2-0 or 3-0 stock acceptable. Avoid areas flooded more than 25% of the year. It is naturally absent or rare on the wettest sites, such as lower floodplain terraces, permanently inundated areas, and swamps with peat soils. Considered interfering vegetation on some sites/locations.
	Carya cordiformis (bitternut hickory)	○	○	○	◐	▲	▲	▶																	■	■			■	■	■	■	□	▶	▼	▶	▶	**Mature:** hickory wilt (*Ceratocystis smalleyii*).	Large bareroot 2-0 or 3-0 stock. Large taproot, if not managed in the nursery, can make planting difficult.
	Celtis occidentalis (hackberry)	◐	◐	●	●	▲	▲	▲																	■	■		□	■	■	■			▶	▲	▼	▲		Large bareroot 2-0 stock.
	Gleditsia triacanthos (honeylocust)	○	○	◐	◐	✦	▲	▲																	■	■		□	■	■	■	■		▶	▼	▼	▼	**Mature:** Nectria canker.	Limited stock availability. If available, large bareroot 2-0 stock acceptable. Thorns can develop early, adding to challenge of planting.

Key:

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- ■ Recommend - species generally well-suited for site condition
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- ✦ New habitat

Appendix B: Lowland Reforestation Species Guide (SLIGHTLY REVISED IN 2019)

	Species	Cover Type Suitability Rating				Climate Change Class			Northern Wetland Forest Habitat Type																Soil		Soil Drainage Class											Insect/Disease Considerations	Planting Considerations
		SH - North	SH - South	BH - North	BH - South	Northern WI	Southern WI	Driftless Area	PmLLe	PmLLe-An	PmLNe	PArGy	Larix	AbThArAsp	AbFnThOs	AbFnThIx	ArFnRh	ThAbFnC	ThAbFnIx	FNOn	FnAbl	FnArl-Ix	FnAbArOn	FnUB	Mineral	Organic	Excessively	Somewhat excessively	Well	Moderately well	Somewhat poorly	Poorly	Very poorly	Seedling Flood Tolerance	Shade Tolerance	Browse Preference	Interfering Vegetation		
Native Deciduous	*Juglans nigra* (black walnut)	○	○	◐	◐	▲	▲	▲																	■			□	■	■	■	□		▼	▼	▼	▶		Large bareroot 1-0 or 2-0 stock. Walnut does not tolerate root zone saturation.
	Populus balsamifera (balsam poplar)	●	○	◐	○	▶	▼	▼																	■	■				■	■	■	□	▲	▼	▶	▶		Limited stock availability. Root or stem cuttings best.
	Populus deltoides (Eastern cottonwood)	●	●	●	●	▲	▲	▲																	■				□	■	■	□		▶	▼	▶	▼	**Mature:** prone to wind damage.	Limited stock availability. Root or stem cuttings best.
	Populus tremuloides (quaking aspen)	●	◐	◐	○	▼	▼	▼			■	■		■	■	■	■	■		■	■	■			■			□	■	■	□			▼	▼	▶	▼	**All ages:** periodic defoliation by gypsy moth, forest tent caterpillar. **Mature:** Hypoxylon canker; white trunk rot.	Limited stock availability. Root or stem cuttings best.
	Quercus bicolor (swamp white oak)	◐	●	●	●	▶	▲	▲																■	■	□		□	■	■	■	■		▲	▶	▶	▶	**All ages:** periodic defoliation by gypsy moth, forest tent caterpillar.	Large bareroot 1-0 or 2-0 stock; 3/8" or greater stem caliper, 6 first-order lateral roots. Limited underplanting trials have exhibited good performance. Best establishment and growth on better-drained microsites, such as natural levees, ridges and mounds.
	Quercus macrocarpa (bur oak)	○	●	●	●	▲	▶	▶																	■		■	■	■	■	■	□		▶	▶	▶	▶	**All ages:** periodic defoliation by gypsy moth, forest tent caterpillar. **Mature:** susceptible to bur oak blight (BOB).	Large bareroot 1-0 or 2-0 stock; 3/8" or greater stem caliper, 6 first-order lateral roots. Best establishment and growth on better-drained microsites, such as natural levees, ridges and mounds.
	Quercus rubra (northern red oak)	◐	◐	○	○	▶	▶	▼	■		■		■		■				■	■	■				■		■	■	■	■	■	□		▼	▼	▲	▼	**All ages:** periodic defoliation by gypsy moth, forest tent caterpillar. **Mature:** susceptible to mortality from oak wilt.	Large bareroot 1-0 or 2-0 stock; 3/8" or greater stem caliper, 6 first-order lateral roots. Best establishment and growth on better-drained microsites, such as natural levees, ridges and mounds.
	Quercus velutina (black oak)	○	◐	○	◐	▲	▶	▶																	■		■	■	■	■	■	□		▼	▼	▶	▼	**All ages:** periodic defoliation by gypsy moth, forest tent caterpillar. **Mature:** susceptible to mortality from oak wilt.	Large bareroot 1-0 or 2-0 stock; 3/8" or greater stem caliper, 6 first-order lateral roots. Best establishment and growth on better-drained microsites, such as natural levees, ridges and mounds.
	Salix nigra (black willow)	○	●	●	●	▲	▲	▲			■														■	■				□	■	■	■	▲	▼	▲	▼	**All ages:** defoliation by gypsy moth, forest tent caterpillar, willow flea weevil.	Limited stock availability. Root or stem cuttings best.
	Tilia americana (basswood)	○	◐	●	●	▲	▶	▶												■		■			■			□	■	■				▼	▲	▲	▲		Two-year germinant. Large bareroot 1-0 or 2-0 stock. Can be difficult to obtain seedlings.
	Ulmus americana (American elm)	●	●	●	●	▲	▲	▶					■						■	■	■				■	□		□	■	■	■	□		▶	▶	▶	▶	**Mature:** Dutch elm disease (DED) eventually kills non-tolerant strains.	Standard bareroot 1-0 or 2-0 stock. DED-tolerant stock limited and still in development.
	Ulmus rubra (red elm)	◐	◐	◐	●	▲	▲	▶					■							■				■	■	□		□	■	■	■			▶	▶	▶	▲	**Mature:** susceptible to Dutch elm disease.	Standard bareroot 1-0 or 2-0 stock.
	Ulmus thomasii (rock elm)	◐	◐	◐	◐	▶	▶	▶						■									■		■	□		□	■	■	■	□		▶	▶	▶	▶	**Mature:** susceptible to Dutch elm disease.	Standard bareroot 1-0 or 2-0 stock.

Key:

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- ○ Poor suitability; not found in cover type; silvical characteristics unsuited; available research suggests it would not perform well
- ? Uncertain suitability; not currently found in cover type; performance untested

- ■ Recommend - species generally well-suited for site condition
- □ Conditionally Recommend - species potentially suited for site condition, but may have limitations or is untested
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- ▶ Moderately tolerant/climate little change/browse moderately preferred
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- ✦ New habitat

Appendix B: Lowland Reforestation Species Guide (SLIGHTLY REVISED IN 2019)

	Species	Cover Type Suitability Rating: SH - North	SH - South	BH - North	BH - South	Climate Change Class: Northern WI	Southern WI	Driftless Area	Northern Wetland Forest Habitat Type: PmLLe	PmLLe-An	PmLNe	PArGy	Larix	AbThArAsp	AbFnThOs	AbFnThIx	ArFnRh	ThAbFnC	ThAbFnIx	FNOn	FnAbI	FnArl-Ix	FnAbArOn	FnUB
Native Coniferous	*Abies balsamea* (balsam fir)	●	○	○	○	▼	▼	▼	■		■		■	■	■	■		■	■	■	■	■	■	
	Larix laricina (tamarack)	●	●	○	○	▼	▼	▼	■	■	■	■	■	■		■		■	■					
	Picea glauca (white spruce)	●	○	○	○	▼	▼	▼			■		■			■		■		■	■		■	
	Picea mariana (black spruce)	●	○	○	○	▼	▼	▼	■	■	■	■	■	■	■	■	■	■	■			■		
	Pinus banksiana (jack pine)	●	●	○	○	▼	▼	▼	■															
	Pinus strobus (white pine)	●	●	◒	○	▶	▼	▼	■	■	■	■	■	■				■						
	Thuja occidentalis (white cedar)	●	●	●	◒	▼	▼	▼			■			■	■	■	■	■	■		■		■	■
	Tsuga canadensis (eastern hemlock)	●	○	○	○	▶	▼	▼	■	■	■			■	■	■	■	■	■			■	■	
Edge of Range	*Carya illinoensis* (pecan hickory)	?	?	?	◒		✦	✦																
	Gymnocladus dioicus (Kentucky coffee tree)	?	?	?	◒		▲	▲																
	Platanus occidentalis (American sycamore)	?	◒	?	●	✦	▲	▲																

Species	Soil: Mineral	Organic	Soil Drainage Class: Excessively	Somewhat excessively	Well	Moderately well	Somewhat poorly	Poorly	Very poorly	Seedling Flood Tolerance	Shade Tolerance	Browse Preference	Interfering Vegetation	Insect/Disease Considerations	Planting Considerations
Abies balsamea (balsam fir)	■	□		□	■	■	■	□	□	▶	▶	▼	▲	**Mature:** during periodic outbreaks, spruce budworm can defoliate mixed spruce/fir stands.	Large 3-0 stock or transplants. Does best under partial shade.
Larix laricina (tamarack)	■	■		□	■	■	■	■	■	▲	▼	▶	▲	**All ages:** larch casebearer. **Mature:** increasing damage from eastern larch beetle with lengthening growing season.	Large bareroot 1-0 or 2-0 stock.
Picea glauca (white spruce)	■	□		□	■	■	■	□	□	▶	▶	▼	▲	**Mature:** during periodic outbreaks, spruce budworm can defoliate mixed spruce/fir stands; needlecast diseases.	Large bareroot 2-0 or 3-0 stock.
Picea mariana (black spruce)	■	■			□	■	■	■	■	▲	▼	▼	▶	**Mature:** during periodic outbreaks, spruce budworm can defoliate mixed spruce/fir stands; needlecast diseases; dwarf mistletoe.	Large bareroot 3-0 stock. Direct seeding common.
Pinus banksiana (jack pine)	■	■	■	■	■	■	■	□		▼	▼	▶	▼	**Immature:** Diplodia basal and stem canker; pine root collar weevil. **Mature:** Jack pine budworm defoliates overmature stands; Diplodia shoot blight.	Small bareroot 1-0 or 2-0 stock. Direct seeding common.
Pinus strobus (white pine)	■	□		□	■	■	■	□	□	▶	▶	▶	▶	**Immature:** susceptible to white pine blister rust and white pine weevil.	Standard or large bareroot 2-0 or 3-0 stock. Direct seeding potential.
Thuja occidentalis (white cedar)	■	■		□	■	■	■	■	■	▶	▲	▲	▶		Large bareroot 3-0 stock or transplants. Plantations outside of eastern Wisconsin need browse protection to become saplings.
Tsuga canadensis (eastern hemlock)	■			□	■	■	□			▼	▲	▲	▲	**All ages:** hemlock wooly adelgid is not yet present in Wisconsin but where established has largely eliminated hemlock.	Large bareroot 3-0 stock or transplants. Plantations need browse protection to become saplings. May require cooler aspects in southern planting sites.
Carya illinoensis (pecan hickory)	■				■	■				▶	▼	▶	▼		Large bareroot 2-0 or 3-0 stock. Large taproot, if not managed in the nursery beds, can make planting difficult.
Gymnocladus dioicus (Kentucky coffee tree)	■			□	■	■				▼	▼	▼	▼		Two-year germinant. Large 2-0 bareroot stock.
Platanus occidentalis (American sycamore)	■			□	■	■	■	■		▲	▶	▶	▶	**Mature:** anthracnose is a common aesthetic issue but not a significant health threat.	Standard 1-0 bareroot stock. Top will freeze back in northern planting sites.

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- ✦ New habitat

Cover Type Suitability Rating:
This rating is an estimate of the relative establishment and growth potential for a species within the swamp hardwood (SH) and bottomland hardwood (BH) cover types. Several factors were considered for the rating, including natural occurrence, silvical characteristics of the species, and other research on species performance (see rating definitions in key). Both cover types have been divided into northern and southern regions, based roughly on the tension zone, to reflect differences in species performance. These are only estimates of establishment and growth potential, and foresters will still need to select reforestation species suited to their specific site conditions.

Climate Change Class:
Species are rated regionally (Northern Wisconsin, Southern Wisconsin and the Driftless Area) based on whether suitable habitat is expected to increase >20% by 2100, decrease >20% by 2100, or change by <20% either way by 2100 in future climate scenarios. Species are also rated as potentially having new habitat in Wisconsin.

Wetland Forest Habitat Type:
The Wetland Forest Habitat Type Classification System is a site classification system that is based on the floristic composition of plant communities in wetland forest ecosystems. The system relies on the identification of potential climax associations, repeatable patterns in the composition of the understory vegetation, and differential understory species. The Wetland Forest Habitat Type Classification System for Northern Wisconsin - A Guide for Land Managers and Landowners covers 5 regions in northern Wisconsin. Tree species that naturally occur in each of these habitat types are listed in the table. Species not listed may also be suitable for tree planting in lowland sites, but do not currently grow in these types. This classification can provide a better understanding of the soils, hydrology and nutrient availability in wetland forest systems and help in the selection of suitable reforestation species. For example, there are 12 lowland *Fraxinus* (black ash) types recognized across the 5 regions that vary in understory vegetation, nutrient availability, soils and hydrology. *Fraxinus* habitat types such as FnArl and FnUb (higher productivity group) have the potential to support a higher proportion of non-ash tree regeneration because of higher soil nutrient availability, compared with types such as AbFnThOs.

Soil:
Species are rated based on their ability to grow in lowland soils composed of mineral versus organic material. Mineral soils (or those with shallow organic over a mineral base) tend to be less acidic and more fertile, and support a wider variety of tree species. Deep organic soils, especially sphagnum bogs, tend to be more acidic and less fertile.

Soil Drainage Class:
Drainage class refers to the frequency and duration of wet periods for a soil type in its natural condition. Natural drainage classes are identified by soil type in most Soil Surveys. Species are rated for the range of drainage classes where they may be adapted.

Seedling Flood Tolerance:
The ability of a tree seedling to tolerate seasonal flooding depends on many factors, including the seasonality, depth, and duration of the flood event. Species and stock size also play an important role in determining seedling survival and growth after water inundation. An estimated rating of seedling flood tolerance is provided based on controlled studies, where available, and other silvical information.

Shade Tolerance:
Shade tolerance, or the ability of a tree to survive and prosper under a forest canopy, will vary by species, age and other factors. Shade tolerance is an important consideration for reforestation stock, particularly if underplanting or in areas of dense interfering vegetation. Species are rated as tolerant, moderately tolerant, or intolerant of shade.

Browse Preference:
Species are rated based on their relative deer browse preference. It is important to consider that deer browse preferences and forest impacts will vary by deer population levels, regions, forest composition and structure, and multiple other factors.

Interfering Vegetation:
Species are rated based on their general ability to compete with interfering vegetation in the seedling and sapling stages.

Insect/Disease Considerations:
Listing of important insect and disease considerations. **Immature:** problems of seedlings and/or saplings. **Mature:** problems of mature trees. **All ages:** problems that impact all ages of this species.

Planting Considerations:
Listing of important planting considerations.

Edge of Range Species:
The listed species either have native ranges that currently border southern Wisconsin or have the potential to grow here if moved north. Some of these species (such as American sycamore) have been successfully planted in southern Wisconsin, but most have had limited field testing.

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Contributors

Stand-level EAB silviculture guidelines developed by the Wisconsin DNR were originally released in 2007, with periodic reviews and updates since then. Guidelines were revised using multiple information sources, such as recent research findings, identification of new EAB infestations, economic considerations, and experience gained by implementing previous versions of the guidelines. This version of the EAB Silviculture Guidelines was revised in 2017-18 by the following individuals (listed in alphabetical order):

ADVISORY COMMITTEE

Representatives from affected stakeholder groups including industry, government and private landowners.

Becky Gray (Facilitator)	DNR, Division of Forestry
Janette Cain	Representation: DNR, Division of Forestry
Greg Edge	Representation: DNR, Division of Forestry
Shawn Hagan	Representation: Industrial Land Managers
Sarah Herrick	Representation: DNR, Bureau of Natural Heritage Conservation
Jim Kerkman	Representation: Society of American Foresters
Scott Koerner	Representation: Timber Producers
Scott Mueller	Representation: DNR, Division of Forestry
Don Nelson	Representation: Paper and Pulp Industry
Lee Rahlf	Representation: County Forests
Chris Thies	Representation: Consulting Foresters
Chuck Wagner	Representation: Woodland Owners

DNR TECHNICAL TEAM

Gathered relevant information and provided recommendations that were used for discussions by the Advisory Committee.

Paul Cigan

Colleen Matula

Bill McNee

Chris Plzak

Access road at the Green Bay West Shores Wildlife Area – Sensiba Unit in northern Brown County.

PUB-FR-767-2019

WISCONSIN DEPT. OF NATURAL RESOURCES

WISCONSIN DEPARTMENT OF NATURAL RESOURCES
NOTICE OF FINAL GUIDANCE & CERTIFICATION

Pursuant to ch. 227, Wis. Stats., the Wisconsin Department of Natural Resources has finalized and hereby certifies the following guidance document.

DOCUMENT ID

FA-20-0026

DOCUMENT TITLE

Emerald Ash Borer Silviculture Guidelines

PROGRAM/BUREAU

Forest Health, Applied Forestry Bureau

STATUTORY AUTHORITY OR LEGAL CITATION

S. 823.075, Wis. Stats., and NR 1.25 and NR 40, Wis. Admin. Code

DATE SENT TO LEGISLATIVE REFERENCE BUREAU (FOR PUBLIC COMMENTS)

2/10/2020

DATE FINALIZED

4/6/2020

DNR CERTIFICATION

I have reviewed this guidance document or proposed guidance document and I certify that it complies with sections 227.10 and 227.11 of the Wisconsin Statutes. I further certify that the guidance document or proposed guidance document contains no standard, requirement, or threshold that is not explicitly required or explicitly permitted by a statute or a rule that has been lawfully promulgated. I further certify that the guidance document or proposed guidance document contains no standard, requirement, or threshold that is more restrictive than a standard, requirement, or threshold contained in the Wisconsin Statutes.

Carmen Hardin   March 27, 2020

Signature   Date