DIVISION OF FORESTRY
ASH MANAGEMENT GUIDELINES

August, 2020

DEPARTMENT OF NATURAL RESOURCES

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INTERNAL POLICY FRAMEWORK INFORMATION – GUIDELINES

These guidelines are a procedural document of the Division of Forestry. This page summarizes relevant internal policy information.

Document approved by:

/s/ Forrest Boe_____ Date: 12/03/2020_____
Forrest Boe, Director
Minnesota Department of Natural Resources, Division of Forestry

Title of Guidelines	**Ash Management Guidelines**
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Related Division Policies	**DP27 Using ECS Information in Silviculture Prescriptions**
Related Division Procedures	**Climate Adaptation and Mitigation in Natural Resource Management** **Regeneration Monitoring: Procedures and Standards**
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INTRODUCTION

Minnesota is home to more than 1 billion ash trees, making the ash genus (*Fraxinus*) the second-most common hardwood tree genus in the state, surpassed only by the genus *Populus*. The ash-killing beetle emerald ash borer (EAB) was discovered in the United States in 2002. It was found in Minnesota in 2009 and is now present in 35 states and five Canadian Provinces. As of June 2020, EAB has spread to 23 counties. EAB can spread rapidly in infested firewood, logs, and ash nursery stock. EAB has infested Minnesota's forested areas in counties where it has been established longest in urban settings. Experience from other states has shown that EAB kills all ash 1 inch in diameter and larger. This level of potential impact is slightly greater than what occurred with American elm following the introduction of Dutch elm disease to Minnesota.

Emerald ash borer is expected to expand and infest all of Minnesota's ash forests resulting in significant impacts to the ash resource including widespread tree mortality, loss of forest cover and habitat, and reduced hydrologic function. It is likely that the vast majority of ash trees in Minnesota will be killed by EAB regardless of the type or magnitude of preventative or treatment actions taken, but it may take decades for this to occur. Moving infested firewood is the major cause of spreading EAB to new locations. The best way to prevent spreading EAB is to not move firewood and actively manage ash stands with EAB infestation.

The large extent of the ash resource (Figure 2), particularly Wet and Floodplain Forest Native Plant Communities (NPCs) containing black, white or green ash, suggests that management actions will not occur in all stands before EAB is established throughout Minnesota. Forested sites will likely be altered or lost.

PURPOSE AND SCOPE

Purpose

In 2011, the DNR published Operational Order 119, Ash Management on DNR Administered Lands, to provide agency-wide guidance to mitigate the potential ecological impacts associated with the loss of Minnesota's ash species through attack by EAB. A steering committee has been established to oversee the implementation of this order. Each division will:

- develop and periodically renew ash management guidelines
- implement forest management operations in ash stands by regenerating or reestablishing non-ash tree species or other appropriate vegetation
- support adaptive forest management capacity by developing projects that increase ecological resiliency of forest communities containing ash

Scope

Guidelines have been updated where ash is the **main forest cover type and primarily in Wet Forest Native Plant Communities** (**NPCs)** where ash is present in sufficient quantity for sustainable timber harvest. Susceptibility of forest stands to EAB will vary depending on the proximity to known infestation, expected rate of spread, amount of ash basal area, tree size class distribution, and other site factors.

GOAL AND OBJECTIVES

Goal

Maintain and protect ecosystem values associated with wet-mesic ash forests for long-term sustainable forest management including timber production, water quality, hydrology, soils, and wildlife habitat.

Objectives

1. Capture timber volume in stands with active EAB infestation
2. Implement timber harvest operations and regeneration methods to maintain water regulation and minimize loss of forest cover to shrub, grass or sedge dominated habitats
3. Maintain forests by successful establishment of non-ash species to increase stand diversity and resilience in accordance with division climate adaptation and mitigation guidelines
4. Use natural or artificial regeneration practices to successfully establish economically and ecologically appropriate replacement tree species.

GUIDELINES FOR STANDS WITH ASH

It is important to use professional judgement when evaluating ash stand examinations for management. The amount of ash basal area retention and size of canopy opening for stand prescriptions may differ significantly when working in an ash-dominated stand when compared to a mesic hardwood or floodplain forest where ash is present as small inclusions or scattered trees. A site assessment during the growing season (May-September) is recommended for evaluating soils, depth to water table, advance tree regeneration and other factors. Refer to the Stand Assessment Checklist in Table 1 for step-by-step guidance.

Protect Hydrology

A guiding principle for all ash management decisions is to protect hydrology and water regulation using timber sale best management practices and adequate retention of live trees. Black ash, because of its abundance on some sites, often regulates water levels in the stand during natural stand succession. If black ash-dominated stands are clearcut without prescribed overstory retention or die due to flooding, native bark beetle outbreak, or EAB infestation, water levels could increase, “swamp,” and convert to shrub plant communities dominated by speckled alder, bluejoint grass, fowl manna grass, reed canary grass, lake sedge, or cattails.

Transition Sites to Non-Ash Species

Prescriptions that transition stands away from ash dominance while providing favorable conditions for initiation of other ecologically suitable native tree species will be determined based on local forester experience, site factors, favorable tree species in Table 3 and Table 4, NPC tree suitability, and assisted migration guidance. For example, research in the Lake States and silvicultural trials in Minnesota indicate that regeneration success to non-ash species may be best achieved using regeneration methods that align with natural disturbance stand dynamics. Field staff are strongly encouraged to implement tree planting, live staking and direct seeding projects with support from the Silviculture Program budget and external grant funding sources.

OUTCOMES

The intended outcomes of the ash management guidelines are to:

- Report all new EAB infestations on DNR lands outside the generally infested area to the Region forest health specialist. Within generally infested areas, report using the GLEDN app or EDDMaps
- Monitor the effects of silvicultural treatments on ash and non-ash growth and survival through scheduled regeneration surveys, climate adaptation projects, and case studies

LAND ADMINSTRATION

Ash harvest and regeneration strategies will help maintain the resilience of ash-dominated native plant communities on Division of Forestry administered lands and all School Trust lands. Exceptions to Division of Forestry guidelines may include regenerating or restoring an ash stand on a unit administered by a partnering division (e.g., Wildlife Management Areas; Aquatic Management Areas) with desired future conditions to favor wildlife habitat or protection of non-timber natural resources. In this case, foresters will work closely with the unit manager and follow the stand treatment and regeneration procedures described in the Activity on Wildlife Management and Aquatic Management Areas document.

STAND SELECTION

Division of Forestry staff will examine and develop silvicultural prescriptions from the planned Annual Stand Exam List (ASEL) provided by the Forest Policy and Planning unit. They will evaluate ash stands for management using the best available forest inventory and native plant community data. Staff have flexibility to defer ash stands for future management opportunities, but this should occur on a limited basis due to poor access reasons or other overriding site constraints. If forest inventory has not occurred in ash stand for at least in 15 years and if it is within 50 miles of EAB, schedule it for a stand examination. Refer to the latest Minnesota Department of Agriculture EAB Status for the most up-to-date locations of confirmed infestations.

STAND ASSESSMENT CHECKLIST

Evaluating ash stands requires a careful assessment of onsite factors during the growing season (May-September). Selecting the appropriate regeneration method and silvicultural strategy for regeneration must balance current demand for marketable timber with STHI harvest targets and ecological and resource protection values. Figure 1 provides a step-by-step prescription workflow sequence for assessing ash stands for potential management.

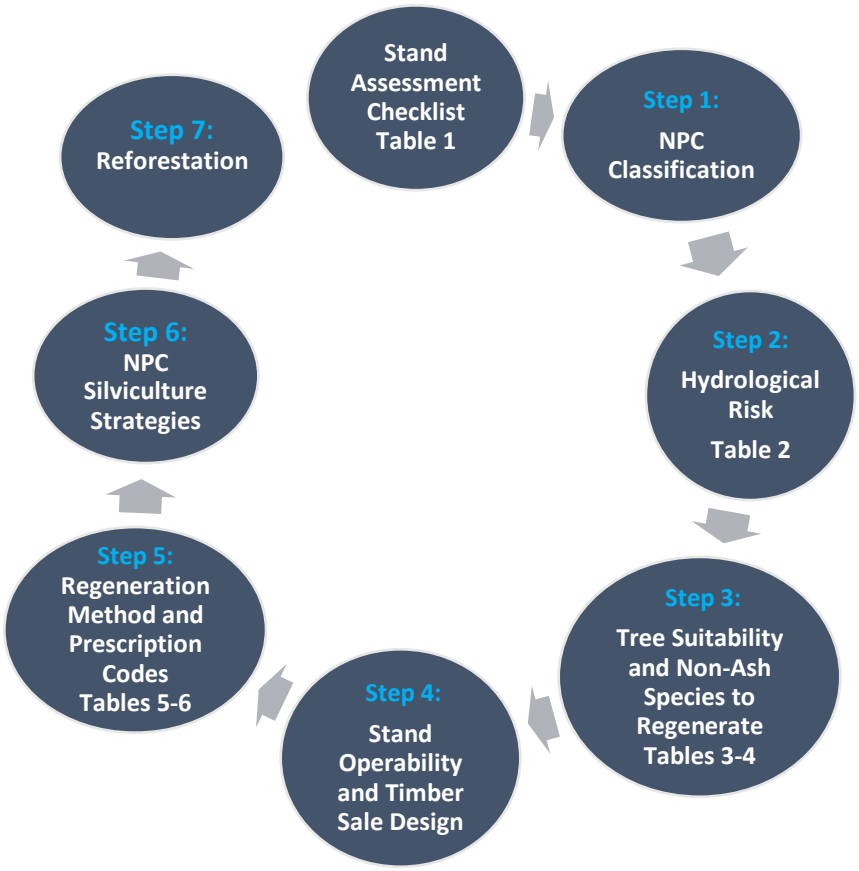

Figure 1. Stand prescription workflow sequence.

Use the Stand Assessment Checklist in Table 1 to determine feasibility for managing ash stands. The stand examination assessment questions can assist foresters prior to completing a prescription. A thorough assessment of current stand conditions is necessary for making management decisions because the forester must decide:

- if the stand can be managed according to guidelines,
- if the stand can be partitioned into harvest and reserve or undisturbed areas, or
- if the stand is not suitable for management due to several constraining factors that result in a stand inventory alteration or deferral.

Answering yes to the majority of questions in the stand assessment checklist may indicate that a stand can be managed sustainably. Individual answers may vary considerably from site to site, however, and in some cases the site checklist may not provide a definitive course of action. Exercise professional judgement when moving forward with a marketable timber sale and reforestation treatment to minimize the loss of forest cover and conversion to non-forest habitat.

Table 1. Stand assessment checklist and questions for determining if ash stands can be sustainably managed.

Stand Assessment Checklist	Yes	No
1. Determine the NPC class by completing an ECS worksheet in the field or confirming the status of NPC mapping by checking the location in Quick-Layers. Refer to Division Policy 27: Using ECS Information in Silviculture Prescriptions for more information.		
2. Assess hydrological risk.		
• Is the hazard rating from Table 2 less than high?		
• Is the anticipated removal of timber volumes greater than 10 cords per acre?		
• Do individual ash trees appear healthy with crowns not exhibiting EAB damage, dieback or decline?		
• Is there a minimum of 10 non-ash trees per acre present in co-dominant or dominant crown classes reasonably distributed throughout the site?		
• Are there mucky pools and hollows across the treatment area? Or grass-dominated lawns with standing water?		
• Is the organic soil or peat over mineral less than 12 inches in mid-summer?		
• Is the depth to water table greater than 12 inches and seasonal flooding limited in mid-summer?		
• Is the drainage not impeded by roads, culverts, beavers, or other impounding factors?		
3. Assess the potential for non-ash regeneration from Table 3. If desirable, calculate the site index by taking height and tree core measurements from 2-3 mature dominant and co-dominant ash trees. Refer to the Site Index section for additional guidance.		
• Is the non-ash regeneration potential moderate or high?		
• Are non-ash trees present in desirable species, at a minimum of 200 stems per acre and 2 ft. tall, and reasonably distributed throughout the site?		
• Is the site index rating greater than 45?		
4. Determine the growth stage (young, mature, old) that best represents the stand conditions found onsite and match the desired successional pathway with the regeneration method, gap size and basal area retention for meeting management objectives and the desired future condition. Refer to the silviculture strategies by natural disturbance agent for WFn55 or WFn64.		
5. Review Table 4 to determine non-ash tree species for artificial regeneration. Is there an opportunity to increase non-ash tree abundance naturally? Review the reforestation section for artificial regeneration options such as tree planting, live staking or seeding.		
6. Assess stand operability, landing locations, skid trails layout and options for slash disposal.		
• Is stand access good or excellent?		
• Can the stand be partitioned into harvest and reserve areas?		
• Can the ash type be designed as a cutting block or combined with other stand cutting blocks?		
7. Review Table 5 and Table 6 to evaluate the regeneration method, gap size opening, and basal area retention options.		
8. Assess understory vegetation and herbivory		
• Do the shrub, sedge or grass life forms collective cover occupy less than 50% of the ground layer allowing for establishment of desired crop trees?		
• Is animal herbivory present on trees or shrubs?		
9. Document the NPC, growth stage, management objective, desired future condition, harvest method and treatment plan in the prescription database.		

Step 1
NATIVE PLANT COMMUNITY CLASSIFICATION

The Division of Forestry manages about 120,000 acres of productive ash for multiple values. Figure 2 shows the distribution of ash and lowland hardwood forest cover type on state lands in proximity to EAB-damaged trees (including lands administered by divisions of Fisheries and Widlife, Ecological and Water Resources, and Parks and Trails. Ash is present in Mesic Hardwood, Floodplain Forest, and wet forest Ecological Systems in Minnesota (MN DNR, 2003). The most up-to-date NPC mapping can be found in the DNR Quick Layers under Land Cover.

A field classification and evaluation of the NPC will help determine and prioritize which stands are suitable for timber harvest and regeneration. Mesic hardwood, floodplain, or wet forest sites with a drier-than-normal moisture profile may support greater proportions of non-ash tree regeneration. However, post-harvest shrub, sedge, and grass response on sites will increase competition with non-ash seedlings, creating a potential need for stand release treatments (WI DNR 2018).

Due to the persistence of saturated soils, the greatest concern for negatively impacting site hydrology is black ash stands classified in the wet forest system. When writing prescriptions to reduce ash abundance, consider an appropriate amount of healthy, residual basal area retention during the regeneration phase in the following NPCs:

- Northern Very Wet Ash Swamp (WFn64)
- Northern Wet Ash Swamp (WFn55)
- Northern Wet Cedar Forest (WFn53)
- Northwestern Wet Aspen Forest (WFw54)
- Southern Wet Aspen Forest (WFs55)
- Southern Wet Ash Swamp (WFs57)

Refer to Table 5 for an overview of basal area retention and harvest gap sizes for each of the main silvicultural strategies envisioned for the Wet Forest NPCs.

Site Index

Site index (SI) can help guide silvicultural decision making. The greater the site index, the more flexibility in applying a silvicultural prescription that will not cause long-term alteration of the site.

- Site index: <55: These stands may provide suitable forest management opportunities. Protect hydrology if trees are harvested, especially if ash species make up more than 90% of the total stand basal area. These sites are appropriate candidates for enrichment plantings (≤400 trees per acre), with or without timber harvest or direct seeding non-ash species.

- Site index: ≥55: These stands may provide the most appropriate forest management opportunities. Protect hydrology if trees are harvested, especially if ash species make up more than 90% of the total stand basal area. Encourage natural regeneration harvest of non-ash species, pre- or post-harvest diversification plantings (>400 trees per acre), live staking and direct seeding non-ash species.

Refer to the black ash site index curves for more information. While site index can be helpful in determining potential site quality and expected timber yield for even-aged stands, a thorough assessment of onsite factors provided in the Stand Assessment Checklist in Table 1 will be necessary for evaluating management potential.

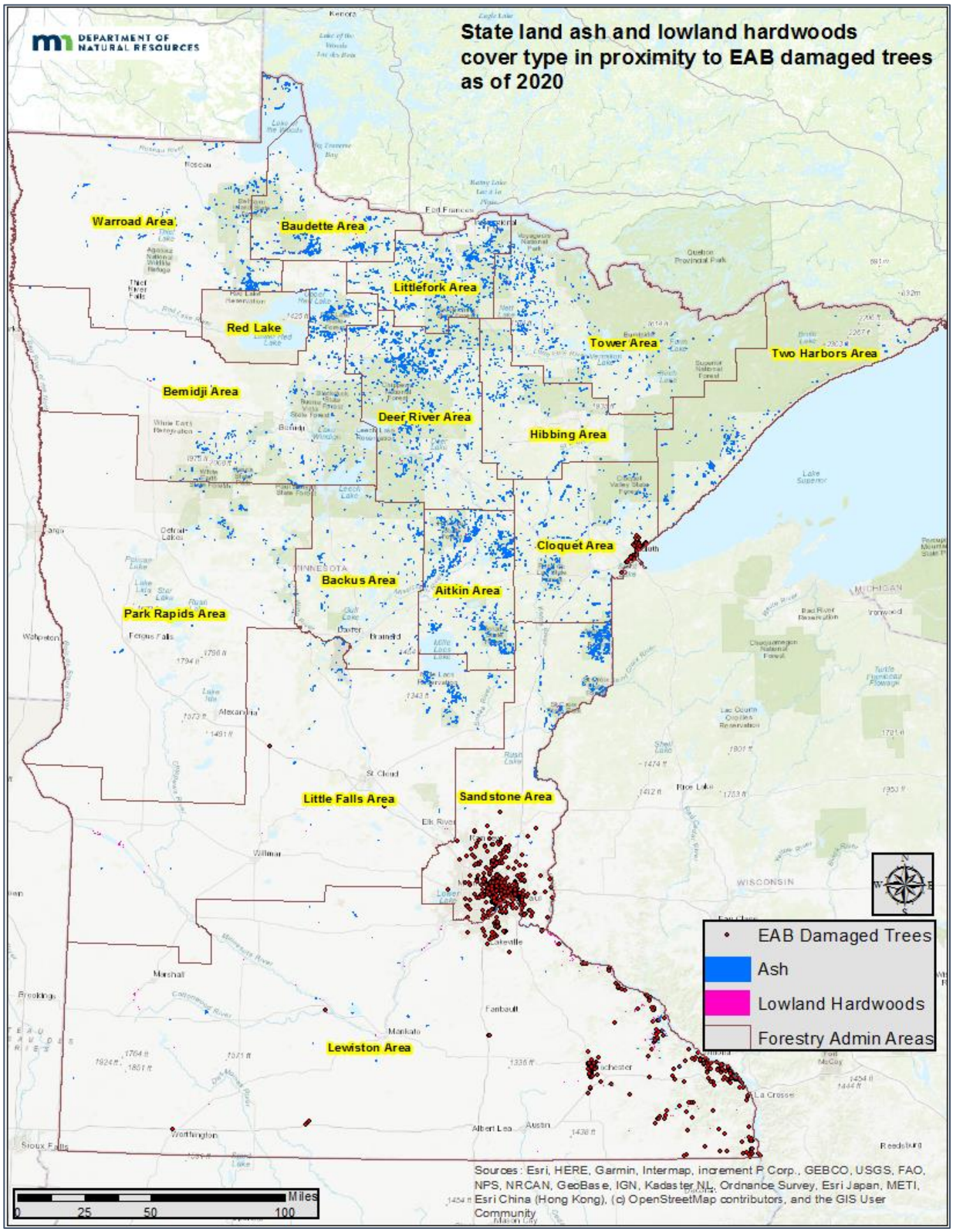

Figure 2. Distribution of ash and lowland hardwood forest cover type on state lands in proximity to trees damaged by EAB.

Step 2:

HYDROLOGY RISK IN NATIVE PLANT COMMUNITIES (NPCs)

The Wet Forest (WF) NPCs are at greatest risk for hydrologic damage ("swamping") if tree cover is significantly altered as with clearcut and overstory removal prescriptions. Swamping can result in tree regeneration failures and significant alteration of ground layer species composition with increases in wetland-dominated species such as speckled alder, beaked hazel, bluejoint grass, fowl manna grass, lake sedge and cattails (Figure 3). In one study, Slesak et al. (2014) found that field simulations of EAB mortality by girdling trees down to 4" DBH and clearcut gaps of 4 acres (Figure 3) for both WFn55 and WFn64 sites resulted in pronounced water table increases compared to group selection gap harvest treatments. This altered hydrologic regime can persist for several years, eventually resulting in a shift to marsh-like conditions (D'Amato et al., 2018) with few or no non-ash tree species.

Figure 3. Examples of an open gap clearcut timber harvest with significant sedge, cattail and black ash seedling response in a Northern Wet Ash Swamp WFn64 NPC.

Table 2 summarizes hydrological hazard risk ratings for EAB in NPCs where ash is present or dominates. We define hazard as the potential for negative impact by EAB or natural disturbance events on hydrology when ash is dominant in a stand. High-hazard NPCs generally have a much greater ash basal area and are vulnerable to swamping and loss of forest cover if ash trees are significantly damaged. An important consideration is the proximity of NPCs to known locations of trees with EAB. Ash stands that are near EAB infestations are more susceptible to attack than those hundreds of miles away. Visit the Minnesota Department of Agriculture for the latest on EAB damage locations within the state. Figure 2 shows the location and abundance of EAB-damaged trees in proximity to ash and lowland hardwood forest cover type and forestry administrative area boundaries. Forestry administrative areas with ash stands in high hazard NPCs within a 50 mile radius of current EAB damaged stands may be considered priority locations for ash management annual planned additions.

While NPCs with low to moderate non-ash regeneration potential may be difficult to regenerate to a fully stocked stand, try to favor natural regeneration where possible. We don't know yet if non-ash species can regenerate and recruit to maintain a forested condition in Floodplain Forests NPCs of southern Minnesota, due to increased flooding events and invasive species threats.

Information on historic natural disturbance rotations by major disturbance agents can be found on the NPC Silviculture Strategies website (MN DNR 2020).

Table 2. Current hydrology risk due to EAB proximity or Infestation in NPCs where ash is present or abundant.

NPC Class Code	Hydrology risk due to EAB proximity or infestation	Non ash regeneration potential	NPC Class Name
MHn46	Moderate	High	Northern Wet-Mesic Hardwood Forest
MHc47	Moderate	High	Central Wet-Mesic Hardwood Forest
MHw36	Moderate	High	Northwestern Wet-Mesic Hardwood Forest
MHs49	High	High	Southern Wet-Mesic Hardwood Forest
WFn64	High	Low	Northern Very Wet Ash Swamp
WFn55	High	Low	Northern Wet Ash Swamp
WFn53	Moderate	Moderate	Northern Wet Cedar Forest
WFw54	Moderate	Moderate	Northwestern Wet Aspen Forest
WFs57	High	High	Southern Wet Ash Swamp
FFn67	Moderate	High	Northern Floodplain Forest
FFn57	Moderate	High	Northern Terrace Forest
FFs59	High	Moderate	Southern Terrace Forest
FFs68	High	Low	Southern Floodplain Forest

Step 3:

TREE SPECIES SUITABILITY AND REGENERATION POTENTIAL

Future crop trees with excellent and good suitability are described in the Tree Suitability tables for WFn55 and WFn64 NPCs. We recommend strip clearcut, clearcut with reserves (coppice), and group selection regeneration methods for creating conditions suitable for the establishment of shade-intolerant to moderately tolerant non-ash tree species (Table 3).

Table 3. Native tree species natural regeneration potential in the ash cover type based on disturbance gap size and shade tolerance. Regeneration potential listed below does not factor in the NPC or the impact that the regeneration method may have on the suitability of hydrologic conditions for a given species.

	Age Class	Even-Aged				Uneven-Aged
	Regeneration Method and Disturbance Gap Size	Clearcut with Reserves Open/Very Large Gap	Seed Tree with Reserves Large Gap	Strip Clearcut with Reserves Large Gap	Shelterwood with Reserves Large/Small Gap	Group or Tree Selection with Reserves Small Gap
Species	**Shade Tolerance**					
Quaking Aspen	Very Intolerant					
Eastern Cottonwood*	Very Intolerant					
Balsam Poplar	Intolerant					
Tamarack	Intolerant					
River Birch*	Intolerant					
Black Ash	Intermediate					
Hackberry*	Intermediate					
Boxelder*	Intermediate					
Silver Maple*	Intermediate					
American Elm*	Intermediate					
Red Maple*	Intermediate					
Swamp White Oak*	Intermediate					
Bur Oak	Intermediate					
White Spruce	Intermediate					
Black Spruce	Intermediate					
White Pine*	Intermediate					
Yellow Birch	Intermediate					
Northern White Cedar	Tolerant					
Basswood*	Tolerant					
Balsam Fir	Very Tolerant					

Key to color-coding native tree species natural regeneration potential:

Regeneration Potential	**Least Favorable**	**Favorable**	**Most Favorable**

*Predicted species "climate winners" based on DNR and USDA Forest Service Northern Institute of Applied Climate Science analysis and modeling.

Table 4. Native tree replacements for natural and artificial regeneration based on research, case studies, and field trials in the Great Lakes region. Many of these regeneration methods and species have only been tested on a small sample of sites. The relative success of each species and method is likely influenced by NPC and onsite factors.

Native Tree Species	Natural[1]	Planting	Seeding[2]	Live Staking	Research [3] or case studies[4] show promising survival and growth performance on ash sites
Quaking Aspen					Undetermined
Eastern Cottonwood*					Yes
Balsam Poplar					Yes
Tamarack					Yes
Black Ash					N/A
River birch*					Yes
Boxelder					Undetermined
Hackberry*					Yes
Swamp White Oak*					Yes
American Elm*					N/A
Disease Resistant Elm					Yes
Bur Oak					Yes
Silver Maple*					Yes
Red Maple*					Yes
Northern White Cedar					Yes
White Spruce					Yes
Black Spruce					Yes
White Pine*					Undetermined
Yellow Birch					Yes
Basswood*					Undetermined
Balsam Fir					Yes

Key to color-coding native tree species natural regeneration potential:

Replacement Potential	Low	Moderate	High

*Predicted species "climate winners" based on DNR and USDA Forest Service Northern Institute of Applied Climate Science analysis and modeling.

[1] Adapted from Suitability of Tree Species by Native Plant Community for Wet Forest NPCs, Minnesota Department of Natural Resources (2020).

[2] Aerial or hand seeding trials have not been attempted on DNR or other public lands in Minnesota.

[3] UMN Extension Guide: Managing Ash Woodlands – Recommendations for Minnesota Woodland Owners.

[4] Great Lakes Silviculture Library: Ash Cover Type

Step 4:

STAND OPERABILITY AND TIMBER SALE DESIGN

Timber sale operations are usually constrained in ash-dominated wet forests due to a combination of factors, including low-value forest products, fluctuating markets, seasonally saturated soil conditions, and poor stand access. Before finalizing a timber sale appraisal, carefully evaluate soil texture, drainage, and depth to semi-permeable layer. Suitable conditions for timber sale operations are expected to decline as winters warm and heavy rainfalls increase in the state due to climate change. Deep snow occurrence early in the season can limit the formation of frost and ability to operate felling and skidding equipment. Timber harvest will occur during frozen soil conditions in ash dominated NPCs and follow division rutting guidelines in situations where soils will be difficult to freeze. Small ash inclusions nested within upland NPCs may be harvested in non-frozen ground conditions where harvesting equipment can reach in and fell trees while minimizing disturbance in the filter strip.

Slash Management

Slash management specifications are tied to both the regeneration plans and the operational needs of the harvest. Slash distribution patterns can be used to protect the site from rutting, soil compaction, nutrient management, as well as provide microsites for seeding. Just as in upland sales, slash distribution is a tool that can work toward or against goals for the site. Be sure to pay attention to slash distribution goals and use where appropriate for your regeneration plan. If you would like further guidance on specific sales, consult your area silviculture lead.

Natural Regeneration

When managing the stand to release currently established advanced regeneration, scattered loose slash can be protective and deter predation. A cut-to-length logging system can produce a very dense slash mat, however, which may prevent established advanced regeneration from moving beyond establishment height. Specifying in the timber sale appraisal “Cut products must be forwarded…” would be counter-productive to the regeneration plan.

Post-harvest stump sprouts, coppicing, or natural seeding can benefit from a slash mat in firm contact with the soil. The mat can prevent root damage from the harvesting operation and result in more vigorous stump and coppice sprouts. The slash mat from a cut-to-length logging system is generally more in contact with the wet soil and breaks down, creating a better seedbed for establishing coarse woody debris (CWD) obligate species such as yellow birch. In contrast, soil-obligate, naturally seeded species benefit from no slash mat. Back-hauling slash can provide for both scarification and protection of regenerating species. Piling can also work in the situation.

Artificial Regeneration

Slash inhibits tree planting and live staking in ash stands in the same manner it does in upland stands. If the regeneration plan calls for artificial regeneration, be sure the slash management specification doesn’t create an inoperable situation for tree planters, especially if using a site preparation tactic such as mounding. The slash mat from a cut-to-length logging system can provide very few natural spaces for planting. Consider piling slash for tree planting or live staking.

Timber Sale Specifications

If using a strip clearcut, shelterwood, or group selection regeneration method, consider whether to leave the slash in the harvest openings or piled at a landing location. Refer to timber appraisal specifications guidance for slash disposal language.

Most State timber sales will use either one of the following slash disposal specifications:

- *Tightly pile slash on landings as designated by Timber Sale Administrator. Piles should be free of dirt, stumps, root wads, and prohibited materials. Piles should be placed at a specified distance away from standing timber*. Or, *lop and scatter slash evenly over the harvest site to within two or three feet of the ground.*

These specifications can be used in combination for specific regeneration goals:

- *Tightly pile slash on landings as designated by Timber Sale Administrator in the designated ash area coupled with lop and scatter slash evenly over the harvest site to within three feet of the ground in remaining sale area.*

When the goal is artificial regeneration in gaps free of slash or to scatter slash on skid trails between openings, use the following:

- *Distribute slash <<across the site, along skid trails, steep areas, within sale boundaries, etc.>>.*

Step 5:
REGENERATION METHODS

This section provides an overview of each major regeneration method where ash is being managed as the primary species in timber sale appraisals. Silvicultural approaches should be different depending on the NPC, especially in black ash-dominated wetlands versus types where black ash is a secondary species. Table 5 can be used as a guide to select a canopy removal gap size and basal area retention plan for the three methods that involve regeneration harvests. Table 6 provides the division prescription coding selections and comments.

Establishing non-ash regeneration is the key to success with any regeneration method. The appropriate regeneration methods described below should be matched with the standards and tactics presented in the reforestation section.

Summary

- Reserve trees serve the purposes of regulating site hydrology, acting as a source for natural seeding, and providing habitat for wildlife.
- Use a timber salvage prescription code (e.g., 1147 or 1320) only when EAB infestation or ash decline mortality is confirmed in a stand.
- To avoid swamping, avoid cleared gaps exceeding one acre, unless specific rationale is provided for open to very large gap harvesting. Exceptions might include timber salvage of EAB damaged trees.
- Do not use a sanitation clearcut harvest prescription code (e.g., 1150 or 1151) to preemptively address ash stands before EAB infestation. Clearcut removal to reduce the spread of EAB is not an effective treatment for landscape-level forest management.
- We see diameter limit cutting occurring in prescription codes identified as clearcut with reserves (e.g., 1111). Many of the ash stands we work with function like uneven-aged northern hardwood cover types. Some trees are suppressed in the understory for years or decades, of poor quality, or growing on an unsuitable microsite. Released seedlings after diameter limit cutting may not respond to the new light environment. Swamping risk will still be a factor.
- Thinning prescription codes (e.g., 1810, 1816, or 1820). Use a regeneration method unless a future opportunity exists for overstory removal of high-quality timber products within 10-15 years of the initial entry, and advanced non-ash regeneration can be released during harvest.

Table 5. An integration of Wet Forest regeneration methods, canopy gap removal sizes, and basal area retention for the four main silviculture strategies envisioned for wet forest NPC classes. The regeneration methods presented in this document are developed primarily for WFn55 and WFn64 NPCs.

Silviculture Strategy	Age Class	Regeneration Method	Canopy Removal Gap Size*	Basal Area Retention	Strip Width
Open/Very large-gap Re-initiate a stand as would severe windthrow or maintain a stand as would selective windthrow by removal of initial-cohort trees in large gaps	**Even-aged** (One age class comprises at least 90% of total stand basal area at rotation)	Clearcut with Reserves (patch or strip)	0.75-1 acre	20-30 sq. ft./acre	Greater than average tree height
		Seed Tree	0.25-0.50 acre	20-40 sq. ft./acre	N/A
		Patch or Shelterwood	0.25-0.50 acre	30-50 sq. ft./acre	Less than average tree height
Large-gap Re-initiate a stand as would severe windthrow or maintain a stand as would selective windthrow by removal of initial-cohort trees in large gaps	**Two-aged** (Two age classes, each greater than 10% of stand basal area at rotation)	Clearcut with Reserves (patch or strip)	0.50-0.75 acre	20-30 sq. ft./acre	Greater than average tree height
		Seed Tree	0.25-0.50 acre	20-40 sq. ft./acre	N/A
		Shelterwood	0.25-0.50 acre	30-50 sq. ft./acre	Less than average tree height
Small-gap Maintain a stand as would natural senescence, disease, or selective windthrow	**Uneven-aged** (Three or more age classes, each greater than 10% of stand basal area at rotation)	Group or Tree Selection	0.10-0.50acre	50-60 sq. ft./acre	N/A
Small-gap	**Non-regeneration**	Thinning	N/A	50-60 sq. ft./acre	N/A

*When selecting canopy removal gap size, gap size should be considered in the context of swamping risk, as 0.5-1.0 acre gaps on WFn64 have been known to swamp out.

Appendix B provides prescriptions examples that can be queried in the Division of Forestry Timber Sales Module (TSM) or Stand Exam Layer (SEL) to review timber sale design specifications and best management practices for maintaining ash stands in a forested condition.

Table 6. Recommended prescription codes for ash management on Division of Forestry administered lands.

Age Class	Regeneration Method	Prescription Code	Comments
Even-aged One age class comprises at least 90% of total stand basal area at rotation. Age difference between oldest and youngest tree in a class is less than 20% of the rotation	Clearcut with Reserves (Patch or Strip Clearcut)	1111	Refer to Appendix B, Table 1 for examples.
	Clearcut with Reserves – Sprouting (Coppice)	1113	Aspen is a significant component of the site and is the target regen species. Refer to Appendix B, Table 1 for examples.
	Clearcut with Reserves – Natural Seeding	1117	Refer to Appendix B, Table 1 for examples.
	Clearcut with Reserves, Artificial Regeneration	1119	Use only with clearcut with reserves, patch, or strip cutting prescriptions with intended planting, seeding or live staking. Other artificial regeneration actions should correspond to the most appropriate two or uneven-aged harvest method listed below.
	Seed Tree	1120, 1121	Refer to Appendix B, Table 2 for examples.
	Shelterwood "Strip-Shelterwood"	1130	Harvest cuttings are oriented in strips and residual trees serve as shelter or seed for the regenerating cohort. Refer to Appendix B, Table 3 for examples. Reserve strips should be 1/3-1/2 of stand area to minimize hydrologic risk.
	Shelterwood with Reserves	1131	Refer to Appendix B, Table 3 for examples.
	Salvage with Reserves, Clearcut I &D	1147	Use only with stands that have confirmed EAB or ash decline mortality
	Sanitation with Reserves, Clearcut	1151	Do not use; clearcut removal or felling of most trees to reduce the spread of EAB (e.g., ash phloem reduction) is not an effective treatment.
Two-aged (Two age classes, each greater than 10% of stand basal area at rotation)	Clearcut with Reserves Patch or Strip Clearcut	1210	Use only when the goal is maintain or create two distinct age classes.
	Clearcut with Reserves – Sprouting (Coppice)	1212	Use only when the goal is maintain or create two distinct age classes. Refer to Appendix B, Table 4 for examples.
	Clearcut with Reserves – Natural Seeding	1216	Use only when the goal is maintain or create two distinct age classes.
	Clearcut with Reserves, Artificial Regeneration	1218	Use only with two-aged clearcut with reserves, patch, or strip cutting prescription where no advance regeneration is present. Other planting or seeding actions should correspond to the most appropriate harvest method listed in the table.
	Seed Tree with Reserves	1220	Use only with two-aged seed tree with reserves where advance regeneration is present. Refer to Appendix B, Table 4 for examples.
	Shelterwood with Reserves	1230	Use only with two-aged shelterwood with reserves where advance regeneration is present. Refer to Appendix B, Table 4 for examples. Reserve strips should be 1/3-1/2 of stand area to minimize hydrologic risk.
Uneven-aged (Three or more age classes, each greater than 10% of stand basal area at rotation)	Group Selection	1315	Refer to Appendix B, Table 5 for examples. Reserves should be 1/3-1/2 of stand area to minimize hydrologic risk.
	Group selection, Salvage	1320	Use only with stands that have confirmed EAB mortality or ash decline.
	Single Tree Selection	1330	Use for removal of poles or sawtimber and the goal is to initiate a new age class of non-ash species.
Non-Regeneration	Thinning	1810, 1816, 1820	Ash prescriptions should be designed to regenerate or accelerate the establishment of a new age class of non-ash species, or to release advance understory regeneration. **Use a regeneration code** except in limited situations where a future opportunity exists for overstory removal of high quality timber products within 10-15 years of the initial entry.

Clearcut with Reserves

Clearcut with reserves is an even-aged regeneration method where removal or felling occurs in a single cutting to promote regeneration of intolerant and mid-tolerant species. The silviculture strategy is stand re-initiation that emulates severe windthrow to create open to very large gap habitat using a clearcut with reserves harvest method (Table 5). Reserve trees, both ash and non-ash, are left randomly scattered as singles, clumps, or strips to occupy a minimum of 5% the cutting area, or 20-30 square feet of residual basal area. Reserve trees serve the purpose of regulating site hydrology, acting as a source for natural seeding and providing habitat for wildlife. Black ash is well-suited to serve in this function as it is abundant and physiologically adapted to these hydrologic regimes. Canopy clear-gap removal can range from 0.5 -1 acre, but it is not recommended to exceed one acre. Studies have indicated that swapping can occur in clearcuts up to four acres (Slesak et al. 2014; Erdmann et al. 1987). Additionally, D'Amato et al. (2018) demonstrated that black ash forests can be strongly uneven-aged, consisting of smaller diameter classes that are also older cohorts less likely to respond with vigorous growth following release.

Large gap clearcuts or removal of ash inclusions in Mesic Hardwood or Flooplain Forest systems may be a logistically and financially appropriate prescription tactic. On the other hand, whole clearcutting, or the removal of all overstory trees in one entry, is not a recommended practice in the Wet-Forest (WF) NPCs due to the loss of future seed sources and the high risk of swamping. Field observations confirm that clearcutting more than one acre frequently results in site conversion to cattails, alder swamps or wet marsh. Field trials in Minnesota and Wisconsin confirm that clearcutting in lowland hardwoods results in the lowest density of non-ash tree regeneration and the highest shrub and sedge density (WI DNR 2018; Looney et. al, 2015).

Diameter Limit

A common tactic for clearcut with reserve prescriptions is to specify an ash diameter range for timber removal and reserving all non-ash species (see Appendix B for examples of clearcut with reserves, diameter limit timber harvest specifications). Cutting ash over or under a specified diameter may be necessary in some situations for marketing and economies of scale, especially with smaller timber sales less than 20 acres, or in stands under direct threat from EAB mortality. However, "diameter-limit cutting," often resulting in stand "high-grading," has been shown to reduce timber quality and value over the long term, and results in indiscriminate regeneration openings (Kenefic and Nyland, 2006). Many ash stands function like uneven-aged northern hardwood cover types. Some trees are suppressed in the understory for years or decades, of poor quality, or growing on an unsuitable microsite. Released seedlings after diameter limit cutting may not respond to the new light environment and may be of inferior genetic material. While more research is needed on the direct impacts of diameter limit cutting in black ash-dominated stands before EAB-induced mortality, the practice is not recommended for quality mixed hardwood or ash sawtimber stands.

Strip Clearcut

A common prescription for both seed and coppice tree species on wet-mesic sites in Wisconsin is clearcutting in strips over the course of 2-3 entries (WI DNR 2015; WI DNR 2018). The distinction between strip clearcutting and strip shelterwoods can be confusing due to the amount and purpose of residual trees being left, timing of re-entry to remove adjacent strips, and the desired future condition emphasis on one or two age classes. The width of the strip can vary significantly depending on site factors and management objectives, but is generally between 50-200 feet with removal of approximately 1/3 to 1/2 of the stand at each entry. Strip clearcutting is used when the width of the strips are greater than the average height of trees on the site. Monitoring from Wisconsin DNR swamp hardwood field trials indicates that strip clearcuts provide the best balance between regenerating the

site and protecting site hydrology (WI DNR, 2018). This has been shown to be an effective reforestation method in Minnesota as well. We generally recommend this regeneration method over clearcut with reserve methods due to administrative efficiencies and greater success with regenerating non-ash species (Table 3).

When mature quaking aspen or balsam poplar are in portions of the stand, use regeneration methods such as strip clearcutting to establish a new cohort. Quaking aspen and balsam poplar suckering will help avoid swamping the site (Figure 4). Consider partitioning the stand by designing strips and uncut skip areas along the edges of large wetlands. Minimize the amount of logging equipment traffic in the wettest portion of a stand. If quaking aspen or balsam poplar are not present, partial harvesting may be feasible with other regeneration methods.

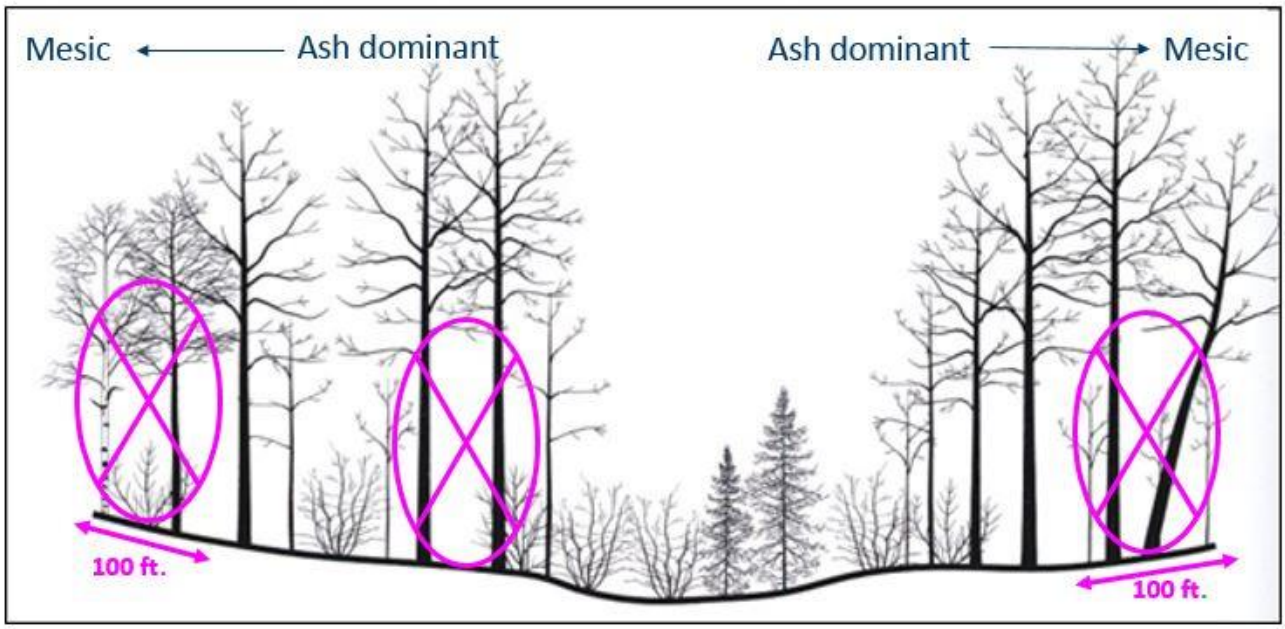

Figure 4. Strip clearcutting harvest example. The "X" refers to the strip location and width for harvest of black ash and non-ash trees.

Seed Tree

Similar to the clearcut with reserves system, a seed tree harvest is an even-aged regeneration method where the majority of timber removal or felling occurs in a single cutting to promote regeneration of intolerant and mid-tolerant species. The silviculture strategy is stand re-initiation that emulates windthrow to create very large size gap habitat (Table 5). Seed trees are selected based on their capacity to produce large amounts of seed for regeneration and should include non-ash species. Common seed tree species include balsam fir, white spruce, black spruce, white cedar, yellow birch, basswood, bur oak, elm, and red maple. Seed trees are deliberately left in scattered or clumped configurations within the regenerating area to retain 20 to 40 square feet of residual basal area. Once a new stand has established, seed trees can be removed by harvest, but are usually left to help regulate site hydrology and contribute to other management objectives.

Shelterwood

Shelterwood is an even-aged regeneration method where a greater amount of tree retention is prescribed compared to clearcut or seed tree systems. This is done in order to alter the space and light environment for establishment or release of mid-tolerant trees that develop underneath the "shelter" overwood. The overwood can also serve as a seed source for new regeneration. The silviculture strategy is to re-initiate a stand as would selective windthrow by removal of initial-cohort trees in

large gaps (Table 5).

The spatial arrangement and distribution of shelter trees can vary depending on the regeneration objectives and is characterized as strip, group, or uniform. The sequence of treatments involves three distinct types of cuttings: an optional preparatory cut to enhance tree vigor and seed production, an establishment cut to prepare the seed bed and initiate regeneration, and a final removal cut to release established regeneration. In uniform shelterwoods the overwood typically makes up 30-50 square feet of residual basal area. In group shelterwoods canopy gaps range from 0.25-0.50 acre.

Overwood trees may be left indefinitely (shelterwood with reserves), especially where understory trees are well established and will not stagnate in partial shade situations. However, an overstory removal after 10-15 years may be appropriate to release seedlings and saplings or capture stand volume before EAB infestation, especially on medium- to high-quality sites with good drainage and favorable operating conditions. The timing and amount of residual trees left as reserves help to differentiate even-aged from two-aged desired future conditions. Wisconsin DNR has found success with both strip and uniform shelterwood regeneration methods in swamp and bottomland habitats for establishing mid-tolerant trees such as yellow birch, red maple, silver maple, swamp white oak, and white pine (WI DNR 2015). Refer to the strip clearcuts in swamp hardwoods prescription trials for more information.

Two-aged Methods

Two-aged methods include a variety of cutting and retention tactics designed to maintain and regenerate a stand with two age classes. Ash prescriptions may include slight variations to the more common practices such as clearcut, seed tree or shelterwood. In simplest form, two-aged stands are the result of intentional retention during a regeneration harvest. These trees are reserved to create a distinct second age class -to obtain structural conditions rather than increasing growth of residual crop trees. The resulting stand may eventually tend towards an uneven-aged condition as a consequence of both extended period of regeneration establishment and the retention of reserve trees that may represent one or more age classes. The final result is a stand composed of two distinct age classes separated in age by more than 20 percent of rotation.

Group Selection

Group selection is an uneven-aged regeneration method that uses harvest of single or multiple trees to create various sized gaps to promote regeneration of mid-tolerant and tolerant species. The result is a stand of trees of three or more distinct age classes, either intimately mixed or in small groups. The silviculture strategy is to maintain a stand as with natural senescence, disease, or selective windthrow to create small-gap habitat (Table 5).

Consider past management and natural disturbance history for the site. What disturbance created the current composition and structure? Does the stand express more severe or selective windthrow origin? Is an uneven-age structure and composition present due to senescence, disease, or minor windthrow? If yes, select a silviculture strategy that favors multi-age composition and structure.

A common approach that employs this strategy is the “string-of-pearls” where multiple gaps are strung together with skid trails connecting those gaps. Often these are set up as logger-directed with minimal marking of harvested timber. Gap centers are either determined with a GPS point or are painted. Gaps can be anchored on non-ash species as a natural seed source. The size and frequency of gaps should balance four things: maintaining enough canopy to not impact site hydrology, providing the necessary light environment for the species to be regenerated, removing enough stand volume to

create a merchantable timber sale and allow for enough merchantable volume for the next stand entry. Partial or tree selection harvesting throughout the stand may add to small gap management objectives while increasing the marketability to local loggers.

Non-regeneration (Thinning)
Non-regeneration methods primarily include commercial thinning where the timber harvest is not intended to establish regeneration or release advance regeneration. This method is still viable on mixed hardwood sites with higher quality timber, good access, and not in imminent danger of EAB infestation. However, this method is not recommended if the increased growth and quality benefits of a thinning are not realized by a future entry within 10-15 years of the initial harvest. Refer to Table 5 for an overview of appropriate silvicultural strategies for WFn55/WFn64 NPCs and Table 6 for regeneration harvest and prescription coding for ash management on Division of Forestry administered lands.

Non-commercial Treatments
If commercial timber harvest is not an option, consider creating canopy gaps through handfelling or girdling to provide light conditions more suitable for the establishment of underplanted or seeded non-ash species. Allow other tree species to naturally seed or develop in the understory. Enrichment plantings or staking live cuttings may be appropriate. Special funding may be needed for this type of work.

Step 6:
WET FOREST NATIVE PLANT COMMUNITIES AND SILVICULTURE STRATEGIES

This section explains the site characteristics and potential reforestation challenges for the two dominant Northern Floristic Region Wet Forest NPCs found in Minnesota (WFn55 and WFn64) where ash management will most frequently take place.

Silviculture strategies are sequences of treatment outcomes designed to emulate natural stand dynamics and promote natural regeneration. They are not silvicultural systems in the traditional sense because they do not cover a full rotation or maintain a particular species or cover type indefinitely. Most involve stand entries over a short period of time that will move a stand towards a forest plan objective, with enough inertia that little silvicultural intervention will be needed to meet long-term goals. We describe management outcomes rather than silvicultural treatments because there are usually several treatments that might achieve the desired outcome. All strategies are based upon our understanding of NPC-specific natural stand dynamics and disturbance regimes. The sequence of outcomes follows the natural pattern; the timing is foreshortened because we intend to harvest sound trees rather than allowing natural senescence.

To learn more about Wet Forest natural stand dynamics, tree species succession and modern tree species composition, visit the NPC Silviculture Strategies website (MN DNR 2020).

The two-page silviculture strategy tatum guides provide the components to write a stand prescription including tree species and conditions necessary to remove or favor gap size concepts, operability concerns, site prep options, regeneration species, and future actions. They provide successional pathway options to achieve the desired outcomes for each main natural disturbance agent and favored tree species for future stand composition. Foresters are directed to select a strategy from the NPC class that best emulates the desired disturbance regime and achieves management objectives at the lowest cost:

- WFn55 re-initiate a stand as would severe windthrow to create open to very large gap habitat
- WFn64 re-initiate a stand as would severe windthrow to create open to very large gap habitat

- WFn55 maintain a stand as would selective windthrow by removal of initial-cohort trees in large gaps
- WFn64 maintain a stand as would selective windthrow by removal of initial-cohort trees in large gaps

- WFn55 maintain a stand as would natural senescence, disease, or selective windthrow to create small-gap habitat
- WFn64 maintain a stand as would natural senescence, disease, or selective windthrow to create small-gap habitat

Step 7:
REFORESTATION

Introduction
Establishing non-ash regeneration is the goal with any regeneration method. The standards and tactics described in this section should be matched with the appropriate regeneration methods as described above and in Tables 5 and 6.

Regeneration Standards
Our current goal is to maintain the ash cover-type as forest by establishing and growing non-ash species to increase diversity and resilience to EAB. To do this, we need a standard by which to measure success of regeneration practices. Table 7 shows the recommended regeneration monitoring schedule with target tree densities and stocking for ash sites. On sites where diversity exists and non-ash seed trees are retained or investments in artificial regeneration are made, we have established a standard minimum density and stocking-level for non-ash crop trees. Without tending, most of the regeneration on a harvested ash wet forest will be ash species.

Standards will be adjusted over time as we gather new information from regional research, case studies, and as we plan for climate-adaptive forestry. To increase our knowledge, conduct more intensive follow-up, such as year two and three regeneration surveys on prescriptions where desired future conditions are for increased non-ash composition and where an investment in artificial regeneration was made. Further, surveying the same plots year after year will increase the value of regeneration surveys when it comes to accurately tracking species planted on the site at low density.

Refer to Regeneration Monitoring Procedures and Standards for more detail on regeneration survey protocol.

Table 7. Regeneration standards for natural and artificial regeneration in northern floristic region ash stands.

Ash*						
Floristic Region	**Growing seasons since initiation**					
	1	**3**	**5**	**8**	**10**	**15**
Northern Natural (ash & non-ash)		Standards Check 5000 Crop TPA (300-500 non-ash) 75% Stocking	Survey Recommended	Standards Check 2000 Crop TPA (100-200 non-ash) 75% Stocking	Survey Optional	Standards Check 1500 Crop TPA (50-100 non-ash) 75% Stocking
Northern Artificial (Open-planting, under-planting, direct-seeding, live-staking)	Standards Check 300-500 non-ash Crop TPA 75% Stocking	Survey Recommended	Standards Check 100-200 non-ash Crop TPA 75 % of plots are FTG Seeding Standards Check at 3 years; 300 Crop TPA 75% Stocking		Standards Check 50-100 non-ash Crop TPA 75 % of plots are FTG	Standards Check 50-100 non-ash Crop TPA 75 % of plots are FTG

* Regeneration surveys include both natural and artificial trees per acre assessed collectively. TPA is trees per acre.

Natural Regeneration

Encourage natural regeneration of non-ash species where possible. Reserve non-ash seed trees from harvest to maintain or increase non-ash tree diversity. Seed source alone may not be enough to encourage significant gains in non-ash species. Where site-prep isn't feasible for creating receptive seedbed, focus harvest and skid trails next to desirable seed trees.

Site Preparation

There are very few examples of mechanical site prep on wet forest sites though there are examples of mounding using shovels, excavators, and even disc trenchers. Efforts to prepare a seed bed for natural or artificial regeneration that actively use mechanical methods should closely document the treatment and resulting vegetation response.

Artificial Regeneration

Regional experience and knowledge of artificial reforestation practices in wet forests is expanding, yet there are many unknowns around potential practices and their long-term outcomes wet forest sites. Trying new things, learning from the work of others, and accurate documentation of ash reforestation projects are critical to the ongoing investment in reforestation efforts in ash forests. Silviculture program staff will continue to document prescriptions in the ash cover-type for short-term and long-term evaluation of

success (Figure 5).

Tree Planting

Planting has been the number-one artificial reforestation technique carried out in black ash wet forests in Minnesota to date, but on many sites it is still too early to tell which species will be the most successful as a replacement for ash (Figure 5). Knowledge of silvics and site factors will be important for species selection and will ultimately determine success. When designing a planting project on a wet forest site, here are a few things to consider:

- Use knowledge of the site and silvics as well as Table 3 and Table 4 for evaluating tree suitability for planting. Also, incorporate what others are learning about potential replacement species (see D'Amato et al. 2018; Looney et al. 2015, and also the Great Lakes Silviculture Library).
- Choose appropriate stock for the site. Moisture deficiency will likely not be limiting to planting establishment but planting efficiency will decrease due to increased travel time between planting holes. Choose lightweight stock (e.g., bareroot seedlings or cuttings) for sites difficult to walk through. Observations indicate that where possible, larger stock will likely have greater growth and survival results.
- Plant sites that have good access for transporting planters and seedlings. As an example, consider planting only a portion of the site if stand is greater than 1/4 mile from where seedlings are staged for planters to load planting bags.
- Unless your intention is to underplant, be certain that your timber sale is cut before committing to large volumes of seedlings. Otherwise have a contingency plan if the harvest is not finished before planting season.
- Provide clear direction to the planting foreman to avoid planting seedlings in pooled water. Planting on hummocks may improve survival during the wet season.
- Alter season of planting to fall for sites that are prone to prolonged spring flooding. Fall may provide better access than spring, but it may be challenging to line up planting stock and planters off-season.

Live Staking

There are several examples from across the Lake States of agencies (USFS, MN DNR, and WI DNR) using or promoting the use of live-staking or cuttings as a means to cost-effectively establish non-ash species on wet forest sites. Live cuttings can be established and grown from willow species, eastern cottonwood, and balsam poplar (balm of Gilead). The steps for collecting and planting are:

1) Identify dormant, young, and vigorously growing branches.
2) If collected in the fall for spring planting, bundle cuttings and store in a cold moist place. If harvested while dormant for spring or fall planting, deploy immediately.
3) Cut 3-4' lengths of most recent growth, cutting the top flat and the bottom at a 45 degree angle.
4) Wound the base of the cutting by scraping away one to two inches of bark and apply rooting hormone
5) Push the angle-cut bottom into wet soil so that about1/2 the cutting is below ground; leave more stem aboveground on sites with greater levels of competition.

Contact your regional silviculturist for more details and assistance if interested in pursuing a project involving cuttings.

Direct Seeding
Direct seeding by helicopter, ATV, or hand may be an option for artificially regenerating non-ash species such as conifers (balsam fir, black spruce, cedar, tamarack, white pine, and white spruce) and hardwoods (birch, bur oak, red maple and sugar maple). Largely, this has not been attempted in Minnesota. Our robust aerial seeding program would lend itself well to trials in direct seeding ash stands.

Release and Stand Improvement
The objective of shifting stand composition in wet forests from ash to non-ash is relatively new. As a result, there are not many examples of tending, if any, in young seedling, sapling, and small tree size stands on wet forest sites regenerating following timber harvest. Mechanical release will likely be needed to avoid a future stand composed primarily of black ash. If crop trees are past sapling size class, this tending would be classified as stand improvement, but the concept is the same: release the selected non-ash crop tree from adjacent crown competition.

Protection
Regeneration surveys should provide a trigger to protect planting or seeding investments if herbivory is identified as problematic to survival and growth of established regeneration. Conifers can be budcapped with paper or treated with a repellent. Trials of other forms of hardwood protection including mesh budcaps are also underway. Preliminary results are pending.

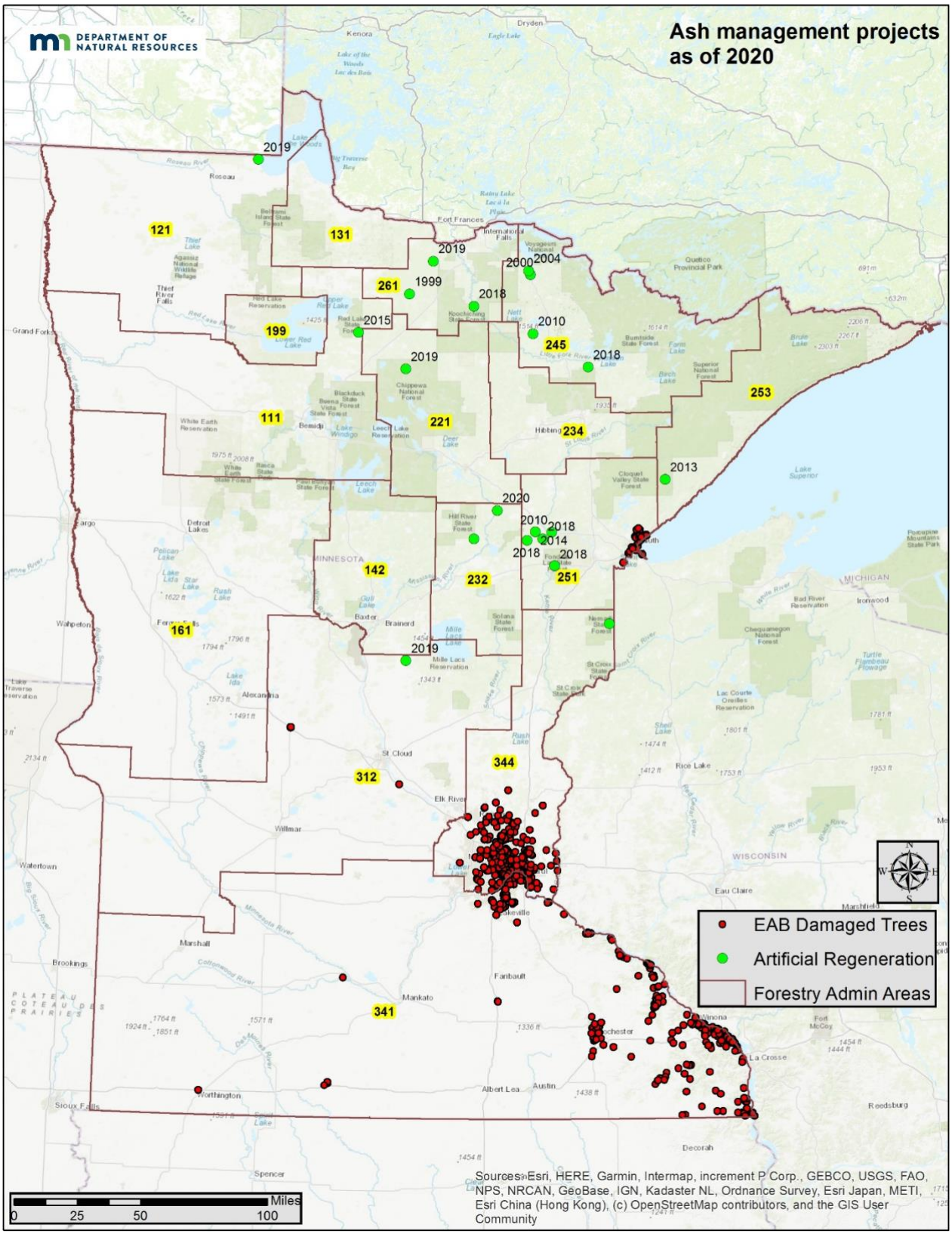

Figure 5. Ash artificial regeneration projects on state lands as of 2020.

APPENDIX A: Stand Assessment Checklist

Stand Assessment Checklist	Yes	No
1. Determine the NPC class by completing an ECS worksheet in the field or confirming the status of NPC mapping by checking the location in Quick-Layers. Refer to Division Policy 27: Using ECS Information in Silviculture Prescriptions for more information.		
2. Assess hydrological risk.		
• Is the hazard rating from Table 2 less than high?		
• Is the anticipated removal of timber volumes greater than 10 cords per acre?		
• Do individual ash trees appear healthy with crowns not exhibiting EAB damage, dieback or decline?		
• Is there a minimum of 10 non-ash trees per acre present in co-dominant or dominant crown classes reasonably distributed throughout the site?		
• Are there mucky pools and hollows across the treatment area? Or grass-dominated lawns with standing water?		
• Is the organic soil or peat over mineral less than 12 inches in mid-summer?		
• Is the depth to water table greater than 12 inches and seasonal flooding limited in mid-summer?		
• Is the drainage not impeded by roads, culverts, beavers, or other impounding factors?		
3. Assess the potential for non-ash regeneration from Table 3. If desirable, calculate the site index by taking height and tree core measurements from 2-3 mature dominant and co-dominant ash trees. Refer to the Site Index section for additional guidance.		
• Is the non-ash regeneration potential moderate or high?		
• Are non-ash trees present in desirable species, at a minimum of 200 stems per acre and 2 ft. tall, and reasonably distributed throughout the site?		
• Is the site index rating greater than 45?		
4. Determine the growth stage (young, mature, old) that best represents the stand conditions found onsite and match the desired successional pathway with the regeneration method, gap size and basal area retention for meeting management objectives and the desired future condition. Refer to the silviculture strategies by natural disturbance agent for WFn55 or WFn64.		
5. Review Table 4 to determine non-ash tree species for artificial regeneration. Is there an opportunity to increase non-ash tree abundance naturally? Review the reforestation section for artificial regeneration options such as tree planting, live staking or seeding.		
6. Assess stand operability, landing locations, skid trails layout and options for slash disposal.		
• Is stand access good or excellent?		
• Can the stand be partitioned into harvest and reserve areas?		
• Can the ash type be designed as a cutting block or combined with other stand cutting blocks?		
7. Review Table 5 and Table 6 to evaluate the regeneration method, gap size opening, and basal area retention options.		
8. Assess understory vegetation and herbivory		
• Do the shrub, sedge or grass life forms collective cover occupy less than 50% of the ground layer allowing for establishment of desired crop trees?		
• Is animal herbivory present on trees or shrubs?		
9. Document the NPC, growth stage, management objective, desired future condition, harvest method and treatment plan in the prescription database.		

APPENDIX B: Stand Prescription Tables

Appendix B provides stand prescription tables for each of the major regeneration methods. The Timber Sales Module (TSM) can be used to search on the cutting block ID for details on the timber appraisal specifications such as harvest species, removal species, diameters, size classes and basal area targets. Stand prescriptions can be queried using the DNRnet Reporting Service by searching on the stand ID and Section Forest Resource Management Plans in the Stand Exam Layer (SEL) Stand Data Summary Report.

As the division increases ash management, it is important that foresters have an understanding of ash harvest prescriptions before and after EAB is established in stands. A query of sold timber sales in TSM where ash is the primary species indicates that 66 percent of stands are managed using an even-aged regeneration method such as clearcut with reserves, seed tree or shelterwood, 25 percent of stands are treated with single tree or group selection, and 10 percent involve thinning or non-regeneration method. A small percentage of stands are being artificially regenerated (e.g., tree planting) following a clearcut with reserves prescription. Figure 1 summarizes the total acres for each regeneration method between FY2012-FY2020.

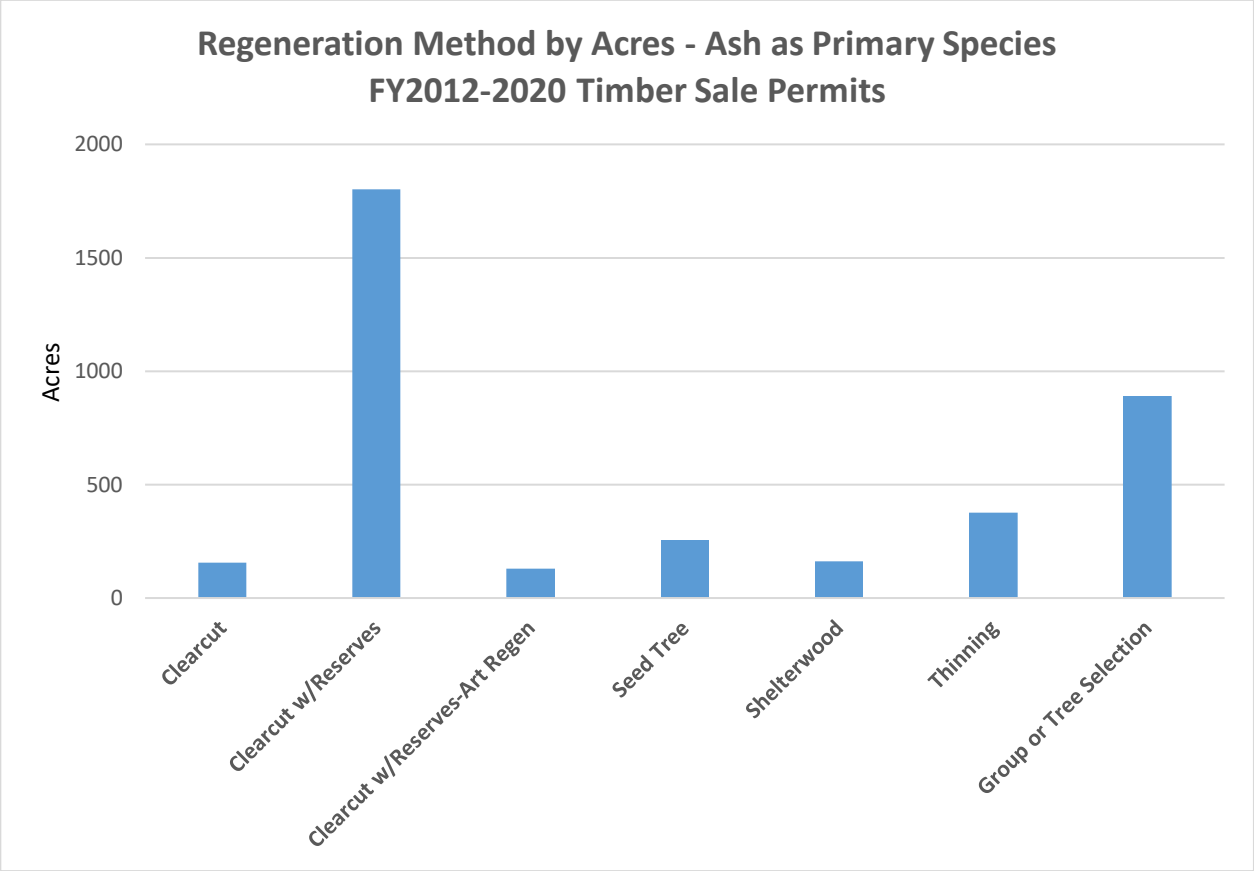

Figure 1. FY12-20 regeneration method and acres of state land for timber sale permits where ash is the primary species.

More recent ash management prescriptions indicate a small decrease in both clearcut with reserves and non-regeneration thinning prescriptions since 2015 (MN DNR, 2019). We attribute this shift in regeneration method to increased staff awareness of regional research into EAB impacts on ash ecosystem and hydrological function.

Clearcut with Reserves

Table 1. Examples of clearcut with reserves timber sale harvest specifications. "Presc. Code" refers to prescription codes entered in the stand exam layer (SEL; Table 4). "SFRMP" refers to Section Forest Resource Management Plans. "RAN" is region-area-number or DNR work area. The silviculture prescription can be queried in the DNRnet reporting service by searching on the stand ID and SFRMP.

Harvest Specifications	Presc. Code	Stand ID	Cutting Block ID	SFRMP	RAN
Harvest all aspen species, white spruce less than 16" DBH, black spruce, ash less than 16" DBH, balsam fir, paper birch, and tamarack. Reserve cedar, red maple, elm, white spruce and ash 16" DBH or greater.	1111	t06524w1060009	15535	NMOP FY18	261
In pure ash portion of the stand (marked on map as thinning) thin ash to 50 BA. Leave all reserve trees marked in blue paint.	1113	t15725w1220164	15938	NMOP FY19_23	261
Harvest main cutting area: harvest all trees except oak and basswood. Ash harvest area: cut all ash greater than 10" DBH. Reserve all oak and basswood trees in main harvest area.	1111	t04925w1080096	11009	Rx Worksheet	232
Harvest ash greater than 7" DBH, aspen spp., and birch. Reserve ash under 7" DBH, maple, elm, and den trees.	1111	t05026w1210270	8769	Rx Worksheet	232
Harvest all merchantable birch, aspen species, and all ash greater than 6" DBH. Reserve all conifer and non-merchantable species, as well as ash less than 6" DBH.	1113	t15731w1170696	14248	NMOP FY17	131
Harvest all ash 8" DBH and greater. Harvest all paper birch and balsam fir (Cutting Block 2). Reserve non-merchantable paper birch and balsam fir. Reserve all ash less than 8" DBH (Cutting Block 2).	1111	t15536w1360685	7692	Rx Worksheet	121
Harvest ash 8" DBH and greater, aspen, balm of Gilead, balsam fir and birch. Reserve cedar and cull ash. Aspen greater than 15" DBH are to be left standing.	1117	t15430w1340531	12375	Agassiz Lowlands Ext	111

Seed Tree

Table 2. Examples of seed tree timber sale harvest specifications. "Presc. Code" refers to prescription codes entered in the stand exam layer (SEL; Table 4). "SFRMP" refers to Section Forest Resource Management Plans. "RAN" is region-area-number or DNR work area. The silviculture prescription can be queried in the DNRnet reporting service by searching on the stand ID and SFRMP.

Harvest Specifications	Presc. Code	Stand ID	Cutting Block ID	SFRMP	RAN
Harvest ash greater than 8" DBH and harvest all merchantable paper birch, aspen, and balm of Gilead. Reserve all cedar, yellow birch, balsam fir, spruce species, maple species, elm, oak, basswood, ash less than 8" DBH and any other unlisted species,	1121	t04516w1350641	14822	MLU_17_18	344
Harvest all ash within cutting block. Reserve 5-10 healthy ash trees greater than 12" DBH per acre.	1125	t05412w1160011	8394	Rx Worksheet	253

Shelterwood

Table 3. Examples of shelterwood timber sale harvest specifications. "Presc. Code" refers to prescription codes entered in the stand exam layer (SEL; Table 4). "SFRMP" refers to Section Forest Resource Management Plans. "RAN" is region-area-number or DNR work area. The silviculture prescription can be queried in the DNRnet reporting service by searching on the stand ID and SFRMP.

Harvest Specifications	Presc. Code	Stand ID	Cutting Block ID	SFRMP	RAN
Cutting unit 3 is a strip-thinning of an almost pure ash stand, harvest 1/3 of ash stand in strips alternating with reserve strips twice as wide as cut strips. Cut strip width will be determined at the presale meeting depending on what type of equipment the permittee has. From the cut strips the logger may reach into reserve strip and harvest balsam 3 sticks and larger, aspen, and balm of Gilead. No harvest of cedar or other reserve species will be allowed in the strips or reserves. Logger should focus harvest strips on areas where removal of declining or suppressed ash is maximized.	Various	t05421w1360533	15027	North 4	251
Harvest ash greater than 8" DBH and not marked and other species listed on permit. Reserve ash less than 8" DBH and marked with yellow, white cedar, spruce.	1130	t06320w1140178	4973	Rx Worksheet	245
Harvest all listed species and ash 7" DBH and larger. Reserve white cedar, spruce, pine, yellow birch and damaged ash less than 7" DBH.	1131	t15025w1240175	8958	Rx Worksheet	221

Two-aged

Table 4. Examples of two-aged timber sale harvest specifications. "Presc. Code" refers to prescription codes entered in the stand exam layer (SEL; Table 4). "SFRMP" refers to Section Forest Resource Management Plans. "RAN" is region-area-number or DNR work area. The silviculture prescription can be queried in the DNRnet reporting service by searching on the stand ID and SFRMP.

Harvest Specifications	Presc. Code	Stand ID	Cutting Block ID	SFRMP	RAN
Harvest in cutting units 1&2 aspen, balm of Gilead, unmarked ash, paper birch marked with yellow paint, balsam 3 sticks and larger. Reserve in cutting units 1&2 ash marked with pink paint, all cedar, elm, maple, unmarked paper birch and balsam less than 3 sticks.	1230	t05421w1360621	15027	North 4	251
Harvest all paper birch, aspen species, and ash greater than 8" DBH. Reserve ash less than 8" DBH, elm, yellow birch, and cedar.	1220	t04925w1040293	12362	North 4	232
Harvest aspen, balm of Gilead, birch, and balsam fir. Harvest ash larger than 6" DBH. Harvest white spruce and black spruce less than 13" DBH. Reserve all cedar, red maple, spruce greater than 13" DBH, and ash less than 6" DBH.	1212	t15927w1090173	12652	Rx Worksheet	131

Group Selection or Individual Tree

Table 5 Examples of group selection or individual tree timber sale harvest specifications. "Presc. Code" refers to prescription codes entered in the stand exam layer (SEL; Table 4). "SFRMP" refers to Section Forest Resource Management Plans. "RAN" is region-area-number or DNR work area. The silviculture prescription can be queried in the DNRnet reporting service by searching on the stand ID and SFRMP.

Harvest Specifications	Presc. Code	Stand ID	Cutting Block ID	SFRMP	RAN
Harvest only black ash within a 66-foot radius from the orang- painted center tree. Only one access lane may be cut between each circle. Access lanes cannot be more than 18' wide. Reserve yellow birch, balsam, white pine, spruce, any other species not listed on permit, and all timber outside circles and access lanes.	1310	t03920w1020019	13031	Mille Lacs Upland Ext	344
Harvest all trees within 80 ft. of marked and numbered center tree except marked and numbered center tree.	1310	t04624w1360118	12879	Mille Lacs Upland Ext	232
Harvest all species listed. In gap harvest areas, cut na 80-foot radius circle around each plot center. Reserve all species not listed and areas marked in blue or red paint. In addition, in gap harvest areas reserve all trees outside of ½ acre clearcuts except for access routes.	1315	t05025w1130121	15071	North 4	232
In gap harvest areas, harvest an 80-foot radius circle around each plot center (plot centers marked with number corresponding to map). Reserve all species not listed above and areas marked in blue or red paint. In addition, in gap harvest areas, reserve all trees outside of 1/2 acre clearcuts except for access routes. In 1/2 acre clearcuts and access routes reserve oak species, white pine, the marked center tree and any species not listed in the appraisal.	1315/ 1111	t05025w1130121	15071	North 4	232
Harvest all sale species within 100 feet of yellow marked trees in ash openings.	1315/ 1212	t15027w1240573	13958	CPPMOP 14_16	221
In "ash thinning" stands, thin to 66 sq. ft basal area, with removal from all diameter classes. Spatial pattern of thinning dependent on equipment available and must be approved by forester before beginning.	1300/ 1117	t14626w1120124	15209	CPPMOP 14_16	221
Harvest ash 8" DBH and larger. Reserve ash 7" DBH and smaller and all other species.	1300	t13936w1180064	9742	Rx Worksheet	161
Harvest aspen, balm of Gilead, balsam fir and harvest ash 11" DBH and greater. Reserve cedar, elm, maple, box elder, paper birch, and ash less than 11" DBH.	1300	t15230w1110206	11890	Rx Worksheet	111

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RESOURCES

Find ash management resources at I:\FOR\Ash Management. An Excel spreadsheet and ash prescription shapefiles can found in the Prescriptions and Timber Sales folder. Ash timber sale permits are located for each forestry RAN. Contact one of the silviculture program leaders for more information.

Another excellent resource is the Northern Institute of Applied Climate Science Climate Change Field Guide for Northern Minnesota Forests. A chapter on Wet Forests provides a summary of NPC system characteristics, vulnerability, adaptive capacity and site-level considerations as well as projected changes for native tree species modeled under low and high climate scenarios.

The Sustainable Forestry Education Cooperative webinar, Site Matters: Quantifying Regeneration After Silvicultural Treatments in Black Ash Stands, by Dr. Marcella Windmuller-Campione also provides a good overview of black ash management, particularly for prescriptions that employ even-aged management such as clearcutting.

GLOSSARY

Ash decline. A general stand decline condition resulting in slow growth, dieback, and occasional tree mortality in ash stands caused by several abiotic factors such as degree of soil wetness, depth to mineral soil and proximity to permanent disturbances such as roads. Symptoms of black ash decline are very similar to symptoms of an EAB infestation, making it difficult to assess landscape-level EAB mortality without confirmation of EAB. Ash stands exhibiting signs or symptoms of ash decline will be managed consistent with the overall goals, objectives and guidelines in this document.

Desired Future Condition (DFC). A broad vision of site vegetation conditions in the distant future. DFCs include a narrative description of the species composition and structure within the overstory, subcanopy, understory, and ground layers. DFCs emphasize desired vegetation conditions when regeneration is established, usually 3-10 years after timber harvest, and at the next planned entry such as a first thinning. Due to the dynamic nature of forest ecosystems, designing a long-term vision for the stand structure over the life of the stand must account for stand in-growth and ecological changes due to natural disturbance events.

Diversification planting. A mix of tree species planted at densities greater than 400 trees per acre.

Emerald ash borer (EAB). Emerald ash borer is a non-native forest insect responsible for the deaths of millions of ash trees throughout the eastern U. S. and southeastern Canada. As of May 2020, EAB is found in 23 counties in Minnesota.

Enrichment planting. A mix of tree species planted at densities less than 400 trees per acre.

Forest cover type. The main tree species composition defined across an area and mapped into relatively distinct units for the purposes of forest inventory, planning and management.

Growth stage. A period of time where tree species composition remains relatively stable during stand maturation. There are typically four stages within forested native plant communities of Minnesota: young, transition, mature, and old. Each growth-stage is characterized by differences in composition and structure. A basic understanding of growth stage stand dynamics is important for predicting the type and quality of vegetation response following a disturbance event. A growth stage is not a desired end goal or required condition for management. It is an ecological construct for understanding changes in stand structure and the processes that help shape and define them.

Native Plant Community (NPC). A group of native plants that interact with each other and with their environment. NPCs are classified and described by hydrology, landforms, soils, and natural disturbance regime (e.g., wildfire, windstorm, insect and disease outbreak). For more information how classification hierarchy is determined, visit the NPC Classification website.

Prescription code. A simplified timber harvest and regeneration categorization using four numerical digits sorted by a major regeneration method. Codes provide the specific harvest method and implied set of treatment action(s) for managing stands to meet management objectives identified in Section Forest Resource Management Plans (SFRMPs), and generally depict the amount and timing of tree removal and leave tree retention accompanying a particular silvicultural practice.

Resilience (stand, forest). Resilience is the capacity of an ecosystem to respond to a stressor or disturbance event by resisting damage and recovering quickly. In the context of EAB, all stands where ash represents the major stand volume are considered highly susceptible to damage and therefore of low resiliency value compared to stands with multiple species. Stand regeneration strategies will consider natural or artificial regeneration to non-ash species to increase future stand resilience to EAB and climate change.

Senescense. The life phase of a tree that precedes natural death.

Silviculture prescription. A planned series of treatments and natural site developments over time, designed to move a site from its current state to a desired future condition. A prescription should include all treatments and activities, including regeneration method, regeneration, and tending. The prescription should also include the sequence and timing of treatments. It can also indicate which stands will be altered, deferred, or where no management action is required. Technical and operational details for the most immediate treatments such as site preparation, regeneration, and regeneration survey are selected in the SEL stand treatment plan. Documented prescriptions are very intentional in describing the desired future condition, the treatments necessary to achieve the desired future condition, and a timeline to reach a free-to-grow condition.

Silviculture strategies. Sequences of treatment outcomes designed to emulate natural stand dynamics and promote natural regeneration. They are not silvicultural systems in the traditional sense because they do not cover a full rotation or have attached the implied goal of maintaining a particular species or cover-type indefinitely. Most involve stand entries over a short period of time that will move a stand towards a forest plan objective, with enough inertia that little silvicultural intervention will be needed to meet long-term goals.

The two-page tatum guide provides the components to write a stand prescription including trees species and conditions necessary to remove or favor gap size concepts, operability concerns, site prep options, regeneration species, and future actions. It provides successional pathway options to achieve the desired outcomes for each main natural disturbance agent and favored tree species for future stand composition.

Foresters are directed to select a strategy that best emulates the desired disturbance regime and achieves management objectives at the lowest cost.

Successional Pathway. The temporal pattern of vegetation change. A successional pathway can show the change in species composition over time with management or by natural succession, and is closely related to growth stage and a chosen regeneration method. We recognize three successional pathways options:

1. Regenerate (or re-initiate): very large scale canopy disturbance that results in harvesting most of the trees and moving mature forests to a younger growth stage, often with less than 10 percent overstory cover.
2. Transition: partial disturbance that results in "transitioning" young forests to mature forest growth stage, often with greater than 30 percent overstory cover.
3. Maintain: small scale or no disturbance that results in "maintaining" mature or old forests, often with greater than 50percent overstory cover.

Swamping. A management condition resulting in a significant rise of the groundwater table and establishment of undesirable vegetation following timber harvest. Loss of evapotranspiration can be highest in clear gaps greater than one acre, or overstory removal where all trees are removed in a single operation, but can also occur in stands where soils are severely compacted or rutted. Swamping frequently prevents, limits, or delays tree regeneration leading to a shift in vegetation and establishment of wetland obligate species such as grasses, sedges, alder, or even cattails.