Managing For Healthy Forests In A Changing Climate

Demonstration Area

The Narrows Wildlife Management Area

West Haven, Vermont

The Narrows WMA is 429 acres in size, 92% forested with the remaining 8% in openings in various stages of vegetative succession from grasses to shrubs. There are calcareous cliffs and talus slopes; dry forested knobs and wetlands; and over 6500 feet of undeveloped lake shoreline. Elevations range from 100 to 500 feet.

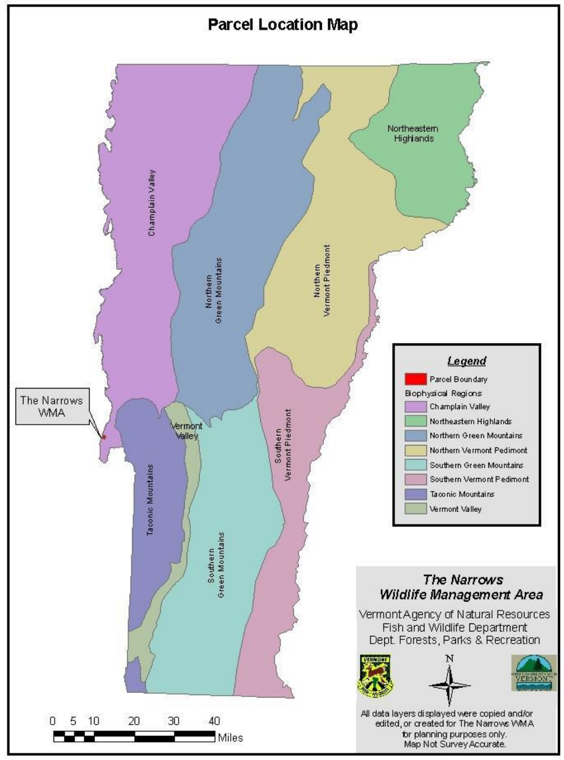
The Narrows contains the highest known concentration of rare, threatened and endangered species than any other site in Vermont. The parcel is also considered highly sensitive from an historic perspective as well, and has three known sites of Native American quarries and villages.

The Narrows Wildlife Management Area (WMA) was created to conserve high quality wildlife habitat. A Vermont Land Trust conservation easement for the property emphasizes the protection of rare, threatened and endangered species and the availability of the property for non-motorized, dispersed recreational activities.

Management Goals for The Narrows WMA are to:

- Protect and enhance rare, threatened and endangered species and their habitat.
- Maintain or enhance the quality of natural community condition.
- Protect and enhance wildlife habitat through management of all seral stages; creation of early successional growth; improvement of deer wintering areas; and protection of unique habitat.
- Enhance opportunities for dispersed non-motorized activities for wildlife-based recreation, particularly hunting, trapping and wildlife viewing. Protect and improve public access.
- Demonstrate exemplary wildlife management practices so that practices applied here may find broader application on private lands.
- Protect historic significance of the property including known and suspected sites.
- Provide sustainable, periodic timber harvesting in appropriate areas to promote wildlife habitat and forest productivity.

Public access to The Narrows WMA is from the



Cold Springs Road in West Haven. There is a small parking area and kiosk near the northeastern corner of the parcel.

Financial assistance for this project has been provided by the USDA Forest Service State and Private Forestry.

TIMBER/VEGETATIVE MANAGEMENT PRESCRIPTION WORKSHEET

Parcel: The Narrows WMA

Location: West Haven, VT

Potential Size: 20 acres

LRMP Page Reference: 58, Sale 1. Plan approved 8/17/12

Summary: Single tree and group selection harvest will be used to create a new cohort, reduce the percentage of unacceptable growing stock overall, and harvest mature and high risk stems. Pre- and post-harvest monitoring and treatment of invasive plants will be conducted within the sale area. Development of vegetation management strategies considering climate change adaptation will be included as part of sale development.

This will be done in cooperation with Sandy Wilmot (FPR Climate Change Coordinator) and Andy Whitman (Manomet Center). This strategy will meet LRMP conditions for research (p. 62) and as a component of the LRMP requirement of an ecological cost-benefit analysis as part of pre-sale considerations (p. 58).

Stand Number	Type	BA	AGS	MSD	Major Species	Regeneration	Acres
1	White pine	120	55	9.2	W. Pine	poor	5
5 (portion)	Oak/hardwood	106	56	10.5	WP, SM, RO	fair	15

Overall Management Scheme/Cutting Cycle/Diameter Goals/Rotation Age *(long-term goals)*:

Stand 5 – oak/hardwood – uneven-aged management, 15 year cutting cycle. Stand 1 – white pine – uneven-aged management; convert to hemlock over time, 15 year cutting cycle.

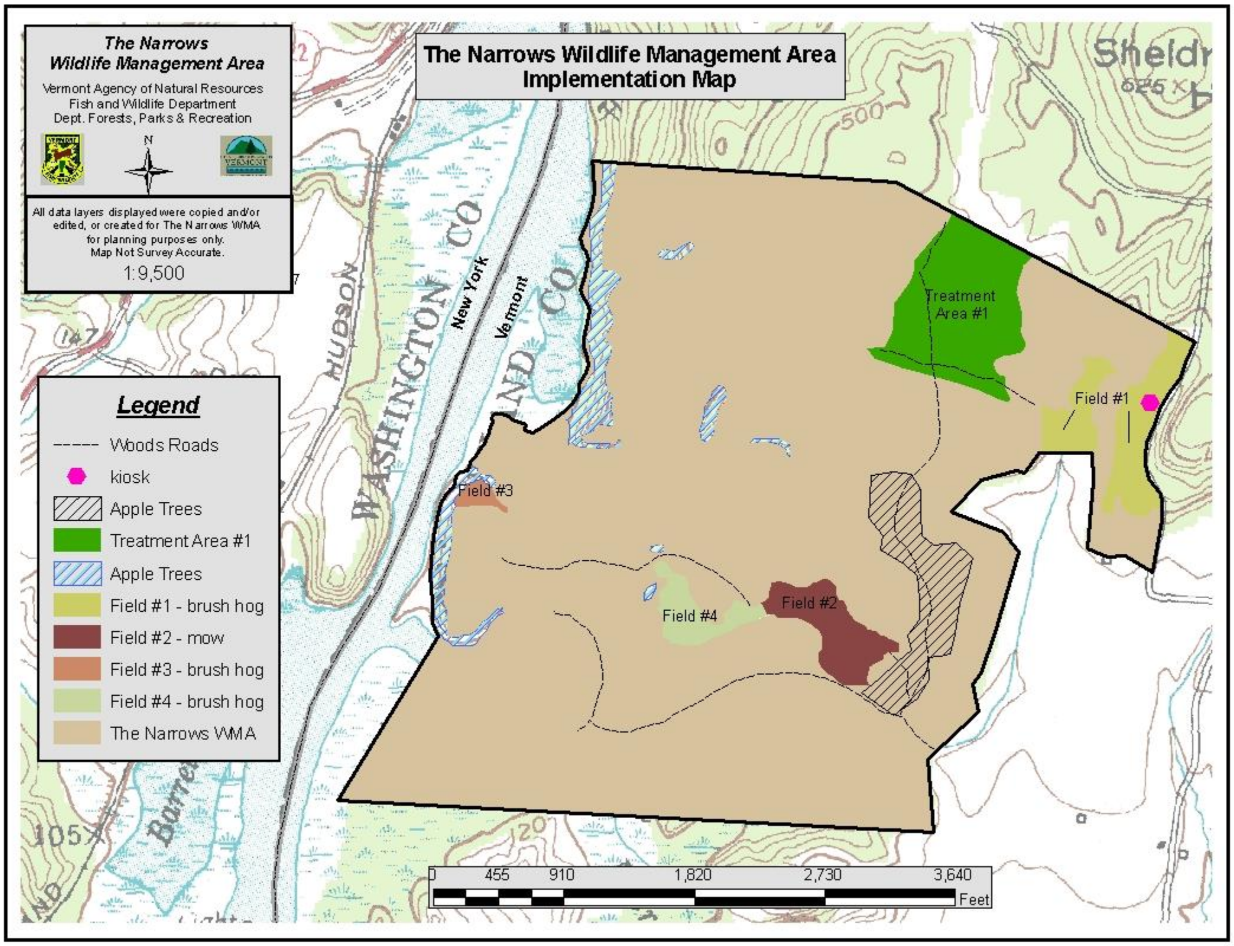
Special Considerations: Protection of rare, threatened and endangered species is an important management goal and easement condition for this WMA. WMA is mapped as summer habitat for Indiana Bat. Follow bat habitat guidance[1]. Mapped vernal pool is outside of treatment area but must be considered as access to sale area is planned[2]. Spread of invasive species has been a concern with past management on this WMA. Management will include treatment of invasive species[3]. The entire WMA is considered sensitive for archeology and contains village and quarry sites. Although this sale area is outside the known sensitive areas, all logging must be done in winter to protect these potential resources[4].

Treatment Objectives: Improve stand composition, structure and habitat without negative impact to natural community condition or sensitive vegetation. Move toward uneven-age stand structure. Retain viable mast component.

Treatment Prescription/Marking Guidelines (by stand):

- Stand 1– white pine stand (natural community: Hemlock Forest). Release regeneration, reduce UGS, and release mast. Thin to maintain stand vigor and value as winter cover. Gradually convert to hemlock.

- Stand 5 – oak/hardwood stand (natural community: Mesic Maple-Ash-Hickory-Oak Forest). Uneven-aged silvicultural treatment including single tree and groups to stimulate regeneration and to release mast species. Groups will be limited in size due to invasive species issues.



1. "Forest Management Guidelines for Indiana Bat Habitat", Vermont Fish and Wildlife Department, February 2009.

2. "Conserving Pool-specialist Amphibian Habitat" (Draft Dec 06), Mark Ferguson

3. LRMP requires pre-sale assessment and post sale treatment of invasive species. Herbicide treatment of invasive species on state land will be guided by "Vermont ANR Pesticide Use Impact Assessment for Invasive Plant Control on State Lands" (July 2006. All plants proposed for treatment are included in Appendix A – "Agency of Agriculture Noxious Weed Quarantine Rule".

4. "Protocol to Protect Historic and Archeological Resources During Timber Harvesting Activities on Vermont Agency of Natural Resources (ANR) Lands". October 2004

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Climate Change Adaptation Strategies for The Narrows WMA, Stands 1 and 5

Andrew Whitman
With revisions added from FPR

Introduction

Climate change will alter many aspects of forests and forest habitats in Vermont (Frumhoff et al. 2007). Although land managers cannot control changes in climate (e.g., warmer temperatures, altered precipitation), they have many options for increasing the resiliency of forests (Gunn et al. 2009). Managing forests under climate change is a challenging undertaking, as the timing and severity of anticipated changes are hard to predict and vary regionally. Climate change adaptation is the planning and application of policies and practices that reduce the threats and impacts posed by climate change. The goal of climate change adaptation in working forests is not to stop climate impacts or preserve the current forest composition, but rather to maintain key forest values. The overarching goals of climate change adaptation in The Narrow WMA are to maintain forest cover and its many economic, social, and ecological values, and achieve the goals established for this management unit (Appendix A).

Summary of Projected Climate Change Impacts on Southern Vermont Forests

Deciduous and mixed forests in Vermont may change significantly in the next 100 years under every climate change scenario (Rustad et al. 2012, Prasad et al. 2007). The extent of oak and pine forest types (including oak-hickory types) is projected to increase and further expand in southern Vermont (Iverson et al. 2008a). Under the lowest emissions scenario, Vermont is predicted to retain its northern hardwood forests. Northern hardwood tree species may achieve increased growth rates under low- and moderate-emissions scenarios due to higher temperatures and a longer growing season, potential CO_2-driven increases in photosynthesis and water-use efficiency, and changes in the nitrogen (N) cycle that increase N availability and plant productivity (Butler et al. 2012). If CO_2 fertilization does not occur, growth rates are projected to increase slightly. Under the higher emissions scenario, growth rates of northern hardwood tree species may decline by 2100 due to temperature stress (Ollinger et al. 2008). Under high-emissions scenarios, oak-hickory forest types are also projected to increase greatly in southern Vermont and northern hardwood forest will modestly decline (Tang and Beckage 2010). Hemlock woolly adelgid (*Adelges tsugae*) population expansion is limited by temperature. Simulations of spread under climate change project that, by the end of the century, eastern hemlock (*Tsuga canadensis*) in northern New England may face the same widespread mortality that has occurred in the southern parts of its range (Paradis et al. 2008). Several northern tree species, including sugar maple (*Acer saccharum*), yellow birch (*Betula alleghaniensis*), and ash spp. (*Fraxinus* spp.), have had periods of decline or reduced productivity in the past 100 years (Mohan et al. 2009).

It is unclear how forest stands and plant and animal communities will respond to climate change. Although there is the potential for large climate-driven range shifts in forest species and types by 2100 (Iverson et al. 2008a), species shifts are not expected to keep up with the rate of climate change, and will likely be delayed (Mohan et al. 2009). Competition may be the dominant structuring force for tree communities in forests (Zhu et al. 2012), so climate change impacts may have to be large to result in changes in regional distributions of tree species. Some tree species may take >100 years before they begin to colonize significant portions of new habitat (Iverson et al. 2005). Therefore, many present and future forest communities may be composed of plant species with migration rates far below those required to track contemporary climate change (Zhu et al. 2012).

Extreme weather (e.g., high temperatures and ozone levels, drought, late frosts, ice storms) might drive mortality that varies from low to high depending on position on slope, site index, soils, and age classes (trees, saplings, and seedlings). For many species on mesic sites, it may be a slow replacement of seedlings and saplings of northern species with those of southern species. For some highly vulnerable species (e.g., eastern hemlock), catastrophic mortality may greatly reduce over-story and possible lack of regeneration could make it difficult to restore mature forest conditions in the long-term.

Proposed Overall Management Approach

Stand Number	Stand Type	Silvicultural Approach	Wildlife Approach[1]	Composition[1]	Cycle of Entries
5	oak/hardwood	uneven-aged management	Maintain mast component and natural community composition.	w. pine = 19% s. maple = 26% red oak = 7% s. hickory = <1%	15-year cutting cycle
1	white pine	uneven-aged management	Maintain softwood cover but do not rely on hemlock for future cover.	w. pine = 83%	15-year to 25-year cutting cycle

[1] The Narrows Wildlife Management Area: Long Range Management Plan. Maciejowksi et al 2011.

Projected Climate Change Impacts

Temperature

Temperatures are projected to increase and reduce the productivity of northern hardwood species late in the century. This is expected to slightly increase mortality of over-story trees and increase their susceptibility to pests and disease (Hanson and Weltzin 2000). Southern species (e.g., shagbark hickory, oak spp.) are more resistant to high temperatures (Burns and Honkala 1990). Seedling mortality of northern conifers (spruce, fir, cedar) is greatest at temperatures >90° F (Burns and Honkala 1990). The expected impact of future temperature increases on this site is moderate and its likelihood is high.

Drought

The frequency of short-term (one to three months) drought is projected to at least double (Hayhoe et al. 2007). Drought is expected to increase mortality of over-story trees and increase their susceptibility to pests and disease (Allen et al 2010, Hanson and Weltzin 2000). The well-drained nature of the local soils will likely make vegetation susceptible to drought, except where sub-surface moisture collects in seeps. The expected impact of future drought on this site is moderate and its likelihood is high.

Lack of snow cover

In northern hardwood and spruce-fir forests, the impact of droughts could increase greatly when preceded by winters during which snow cover is inadequate (<25 cm) and intense cold spells occur, making root systems more vulnerable to root kill (Auclair et al. 2010). The expected impact of future lack of snow cover on this site is low to moderate and its likelihood is high.

Wildfire

Climate change may increase the frequency of lightning strikes, dryness, and blocking high pressure ridges, which rapidly dry forest fuels, thereby increasing the probability and extent of fire in Vermont. Modeled predictions suggest that fire severity due to changing weather conditions may increase 10% to 20% overall for the Northeast (Flannigan et al. 2009). Under a range of scenarios, the probability and extent of hardwood forest burned in nearby Quebec was projected to range from a slight increase to a five-fold increase (Drever et al. 2009). Fire in hardwood forests could increase if conditions lead to long, warm periods before leaf out or after leaf fall. The expected impact of future wildfire on this site is moderate to high and its likelihood is low.

Current Challenges

Lack of natural regeneration

Natural regeneration of tree seedlings and saplings in Stands 1 and 5 were sparse and were heavily browsed. Climate change by itself may not significantly affect growth and survival of seedlings and saplings of most species, except for spruce, northern white cedar, and fir seedlings, which can have high mortality in hot and dry years (Burns and Honkala 1990).

Exotic plant species

Invasive exotic plant species were common in Stands 1 and 5 and their presence is a major management challenge. Several exotic species are well established and have significant impact, including Japanese honeysuckle, buckthorn, and barberry. These species aggressively increased after harvest on previously harvested sites. Climate change is predicted to increase the frequency of disturbance events that lead to rapid expansion of exotic species and changes in plant communities (Dale et al. 2001). Because most exotic plant species have high growth rates and long-distance dispersal traits, they have a competitive advantage over native species for colonizing and establishment, especially following ecosystem disturbance (Dukes and Mooney 1999). Climate will hasten the spread of many exotic plant species because: (1) increased forest ecosystem disturbance and stress will facilitate their establishment and (2) rising CO_2 levels enhances the growth and competitiveness of some exotic species (Ziska and Dukes 2011).

Hemlock woolly adelgid (HWA)

HWA is not present at The Narrows WMA, but is found in southern Vermont (VT Department of Forests, Parks, and Recreation 2012). With climate change, the range of HWA is predicted to expand more rapidly, and it may occupy The Narrows WMA in the near future. Milder winters are projected to lead to higher HWA population levels (Dukes et al. 2009), which would increase the risk to hemlock health.

Deer

High deer population densities have resulted in moderate to heavy browsing of all understory species, except exotic species, in the unit (Maciejowksi et al. 2011), including Stands 1 and 5. As a result, the shrub layer, including tree regeneration, is largely absent in many areas. Deer also avoid browsing on exotic plant species to the detriment of native species (Knight et al. 2009). With climate change, winter will be milder and deer population densities can be expected to increase (Rustad et al. 2012).

Soils

The soils are well drained to somewhat excessively drained and so this site is somewhat susceptible to drought (USDA NRCS 2013).

Site Specific Considerations and Recommended Additions to the Harvest Plan

Climate change is expected to increase air temperatures, frequency of drought and forest stress, and pest outbreaks. With these changes, invasive species, tree diseases, and tree pests are projected to become more widespread and threaten forests. Storm damage is projected to increase as well. Therefore, for this site, climate change adaptation focuses on using standard forest practices to achieve greater stand resiliency and vigor and reduce vulnerability. The proposed approach focuses on Management Goals 1 through 3, 6, and 8 (Appendix A).

Almost all of these goals and practices are either already included in the existing plan for The Narrows or are consistent with its goals. Climate change adaptation often simply requires finding opportunities to make small changes to existing landowner goals and practices that increase stand resilience to climate change

Long-term Strategies

This section identifies how the existing plan has goals which are consistent with climate change adaptation.

1. Increase Stand Diversity and Health

Stand resiliency can be achieved by maintaining a diversity of tree ages and species in the stand. This reduces stand vulnerability to losses of age classes and species that are susceptible to climate change related stressors.

a. <u>Aim for diverse-age structure:</u> The stands should be shifted to an uneven-age structure to allow advanced regeneration for in fill if small or large replacement events occur and improve flexibility for managing the stand for financial and biodiversity goals in the future. A diversity of ages means that the stand always has younger, vigorous growing stock (Wilkerson et al. 2011, Gunn et al. 2009). The current plan also suggests this strategy for these stands.

b. Maintain tree species diversity: Tree species diversity at the stand level should be maintained to improve stand-level disease resistance and create greater flexibility for managing stands for a range of silvicultural, financial, and biodiversity goals in the future (Wilkerson et al. 2011). This includes maintaining shagbark hickory in the stand, a southern species that has been projected to increase its range in Vermont and that should be more resilient to future climate conditions than northern species. It also means reducing eastern hemlock densities where it dominates to allow other tree species to enter the canopy and provide canopy cover if HWA kills many eastern hemlock trees. So for Stand 1, where the natural community would be hemlock, aim for a hemlock-northern hardwood mix as a resilience strategy. This goal is consistent with goals for the WMA, including these stands.

2. Reduce the impact of existing stressors on forests

Reducing existing stressors can make ecosystems less vulnerable to stress posed by climate change.

Control invasive understory species: Invasive understory species should be controlled to allow recruitment of regeneration and for the stand in the future (Wilkerson et al. 2011). Control should target portions of the harvest block where harvesting will create canopy gaps and should be applied before and, if necessary, after the harvest (VT Fish and Wildlife Department 2012). Control can include use of backpack sprayers or manual removal to target large and/or vigorous invasive shrubs. This goal is part of the current plan for the WMA, including these stands.

3. Protect soils

Protecting soils is essential for maintaining site productivity. Climate change will likely increase the frequency of extreme events and necessitate consistent use of measures to protect soils from erosion and rutting.

Maintain adequate down woody materials – Developing or maintaining adequate down woody material will replenish soil organic matter, moderate temperatures, and support wildlife habitat. Productive and structurally diverse stands will better adapt to unknown site changes likely to result from climate change. Tops and slash should be placed around stumps of oak and maple species to protect sprouts from deer browsing. This goal is part of the current plan for the WMA, including these stands.

4. Reduce impacts of current stressors to wildlife

By reducing the threats posed by existing stressors, one can reduce the vulnerability of wildlife to climate change. This includes:

- Control the spread of invasive exotic species;
- Maintain/enhance mast component by harvesting to promote crown development of species including oaks and hickories;
- Maintain or enhance the mosaic of forest stands and natural communities for their contribution to wildlife habitat including softwood cover and mast source;
- Protect vernal pools and their habitat value by following vernal pool management guidelines;
- Protect seeps and intermittent drainages where plant diversity is high and uncommon plant species occur more frequently.

Short-term Silvicultural and Operational Practices

All of these strategies were discussed on the ground with the Stewardship Team or management staff and were consistent with existing discussions and strategies for management. Most of these practices have been routinely used on state lands.

1. Apply crop tree release (addresses Goals 6 and 8)

Crop tree release should be applied to grow very large trees in the future for wildlife habitat (e.g., bat roosts, habitat for mature forest species); maintain a vigorous, weather-, drought-, and disease-resistant over-story; and grow trees for the next harvest. It will promote crown expansion, height growth, and diameter growth in the released stems. It should also focus on thinning from below for trees that are declining or poor quality co-dominants or sub-dominants. Crop tree release can be applied to largely maintain canopy closure and thereby reduce the likelihood of an increase in abundance of invasive plant species due to timber harvesting. This practice is a well-established silvicultural technique and often used on state lands. It has not been well tested for combating problematic invasive species. This will increase stand diversity and resiliency and minimize impacts of exotic plant species.

2. Use group selection (address Goals 6 and 8)

Use group selection to create gaps of sufficient size to allow regeneration to overtop invasive species before canopy closure and create additional age classes. Canopy gaps should be about two tree heights across or greater, at least 0.5 acres and up to 2 acres (VT Fish and Wildlife Department 2012). Proposed gaps should be treated before for invasive species and, if necessary, after logging (VT Fish and Wildlife Department 2012). This practice is a well-established silvicultural technique and often used on state lands, though not routinely used to combat problematic invasive species.

3. Treat unacceptable growing stock (UGS) (addresses Goal 8)

Most UGS should be harvested to eliminate cull or other low-vigor trees and retain healthy stems. This will improve species- and stand-level disease resistance by reducing stems vulnerable to disease, pests, drought, or storm damage. Operations should continue to follow already existing agency practices that aim for retaining about 20% of UGS to provide wildlife trees and future down woody material. Standing dead trees should be retained where possible as wildlife trees and for future down woody debris (Bennett 2010). These practices are already applied to state lands and to varying degrees on private lands.

4. Reduce eastern hemlock densities (addresses Goals 2, 3, and 6)

Eastern hemlock is highly susceptible to HWA, which has begun to invade the southern Vermont region. Healthy hemlock trees are more likely to resist HWA and other disturbances. Moreover, if HWA causes very high mortality, then increasing over-story diversity, through removals of over-mature and other low-quality hemlock trees (e.g., crown ratios ≤ 30%) and trees on sites where soils are shallow, will prepare the stand to be able to more rapidly recover. Hemlock trees with crown ratios > 30% that are suppressed should be considered for release as the vigor of these trees should increase following release (Smith et al. 1997) and may become more resistant to HWA (Fajvan 2008). This is a practice that could be used on state or private lands where eastern hemlock is dominant and risk for HWA is high in the next 15 to 25 years.

5. Apply soil BMPs (addresses Goals 1 and 2)

Carefully select time of year for harvest to control soil erosion, spread of exotic species, and create a seedbed for timber species. A winter harvest may reduce the likelihood of an expansion of invasive plant species by minimizing soil disturbance during the harvest, which creates a seed bed for invasive plant species, and provides some protection to rare plant species in the stand (VT TNC 2012). This practice is already used on state lands where invasive species are a problem. However, to create a seedbed for regenerating species that requires soil scarification for seedling establishment (e.g., yellow birch), a summer harvest will be necessary.

Potential Monitoring Practices

The goal of these monitoring practices is to collect information to support adaptive management actions that respond to changed forest conditions (see Table 1).

1. <u>Apply deer exclosures (addresses Goal 6 and 8)</u> – Deer enclosures can be used to both assess and verify deer impacts and protect regeneration in harvest areas. Ideally three or more small enclosures should be used to determine the statistical significance of the impact of deer exclosures. Areas for placing the deer exclosures are paired with non-exclosure sampling sites should be identified and sampled before harvesting (Year 0) and in Year 1, Year 5, Year 10, and Year 15 following the harvest. The following variables are recommended for monitoring: (1) stem counts of tree seedlings and saplings by species and height class, (2) stem counts of invasive plant species by species and height class, and (3) percent cover of a few herbaceous plant species that are sensitive to deer browsing (e.g., *Trillium* spp., *Maianthemum canadense*, *Medeola virginiana*) and fern spp. (VT Fish and Wildlife Department 2012). Depending on the size of exclosure, only a small portion of the enclosure would need to be sampled. This strategy emerged from discussions with the Stewardship Team. This strategy could occasionally be applied to state lands but would be too expensive to widely apply. These variables should indicate whether deer are having a significant impact on the understory plant communities by year 10.
2. <u>Monitor harvest gaps for regeneration and invasive species (addresses Goals 6 and 8):</u> Harvest gaps should be field checked one to two years after harvest to determine whether invasive plant species are suppressing the growth of regeneration (VT TNC 2012). Field checks by year 2 should be able to identify whether control of exotic plant species in harvest gaps is necessary in order to maintain regeneration.
3. <u>Monitor for HWA (addresses Goals 6 and 8):</u> Eastern hemlock should be monitored for HWA. Once it has been detected, surveys for HWA should be conducted every two to three years following Costa and Onken (2006) or similar protocols and for decline (percentage of healthy trees [>30% crown ratio], declining trees [≤ 30% crown ratio], and dead trees). This strategy should be applied in areas at risk to HWA where eastern hemlock is dominant. Field surveys can be used to determine whether harvests should be considered to promote forest regeneration, salvage operations conducted to control fuel loads, or if direct control actions should be considered.

4. Review the site in 15 years for harvesting timber (addressees Goal 8): The site should be evaluated in 15 to 20 years to determine whether a subsequent harvest consistent with land objectives at that time is possible and warranted. This should include an assessed of merchantable timber and regeneration. This is a routine strategy for WMA stands with timber harvesting.

Potential Management Practices

The goal of these management actions is to adapt to three possible indirect impacts of climate change: increased deer populations due to milder winters, more invasive plants due to a more favorable growing season, and HWA due to milder winters (Table 1).

1. Apply deer exclosures (addresses Goal 6 and 8): Deer enclosures can be used to protect regeneration in harvest areas. Ideally three or more small enclosures could be used to protect seedlings and saplings in large harvest gaps. This strategy could occasionally be applied to state lands but would be too expensive to widely apply. These variables should indicate whether deer are having a significant impact on the understory plant communities by year 15. Alternatively more, small temporary exclosures could be applied (10' x 10').

2. Control invasive plant species in harvest gaps (addresses Goals 6 and 8): Harvest gaps should be field checked one to two years after harvest to determine whether invasive plant species are suppressing the growth of regeneration (VT TNC 2012). If necessary, management staff should consider the application of herbicides or manual removal to reduce the impacts of invasive plant species. The staff had already planned to apply this strategy. This is a strategy that should be considered for all state and private lands that have been harvested where invasive plant species are a problem. Field checks by year 2 should be able to identify whether control of exotic plant species in harvest gaps is necessary in order to maintain regeneration.

Reduce impact of hemlock woolly adelgid: Hemlock surveys should be conducted in conjunction with pre-harvest timber surveys in year 15 to determine whether salvage of hemlock is necessary. Vulnerability should be reduced by promoting a diversity of overstory species and forest regeneration, focusing on areas with over-mature and other low-vigor hemlock, and hemlock on drought-prone sites. Hemlock on better sites should be released, minimizing root disturbance. Other HWA control methods may be considered if critical hemlock cover is threatened.

Table 1. Summary of potential monitoring and management actions related to climate change.

Attribute for Management	Potential Monitoring Action	When?	Estimated Monitoring Cost[1]	Potential Management Action	When?	Estimated Management Cost[1]
Deer Damage	Assess deer impacts on regeneration	Year 0, 1, 5, 10, & 15	$750[2]	Install enclosures to protect patches of regeneration in harvest gaps	Year 1	$2000-$8000 (four exclosures; $500 -$2000/ 33'x33'exclosures)[4]
Invasive Plant Species	Assess regeneration and invasive plant species impacts on regeneration	Year 0, 1, 5, 10 & 15	$750[2]	Apply herbicides using backpack sprayers to control exotic plant species	Year 2	$35-$245/acre[5]
HWA	Assess impacts of HWA	Year 7 and 15	$600	Use harvests to promote diversity and hemlock health. Conduct salvage if necessary. Consider HWA control methods.	Year 15	No additional cost[3]
Timber	Assess timber and regeneration	Year 15	No additional cost	Timber harvesting	Year 15	No additional cost

[1] Estimated costs include total cost of materials and labor over 15 years.
[2] Deer damage and invasive plant species monitoring would occur in combined visits, cost $300/half-day visit.
[3]It is recommended that pre-salvage and salvage operations occur only as a part of routine timber harvest operations.
[4] after Nicholas et al. 2007.
[5] after MA Executive Office of Energy and Environmental Affairs. 2013, Kochenderfer et al. 2012.

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Appendix A: Landowner Management Goals

The management goals within The Narrows WMA Long-range Management Plan (Maciejowksi et al. 2011) are to:

1. Protect and enhance rare, threatened and endangered species and their habitat.
2. Maintain or enhance the quality of natural community conditions.
3. Protect and enhance wildlife habitat through management of all seral stages, creation of early successional growth, improvement of deer wintering areas, and protection of unique habitat.
4. Enhance opportunities for dispersed non-motorized activities for wildlife-based recreation, particularly hunting, trapping and wildlife viewing.
5. Protect and improve public access.
6. Demonstrate exemplary wildlife management practices so that practices applied here may find broader application on private lands.
7. Protect historic significance of the property, including known and suspected sites.
8. Provide sustainable, periodic timber harvesting in appropriate areas to promote wildlife habitat and forest productivity.