

Climate Change Adaptation Plan

Protecting Riparian Zones with a Focus on Stream Crossings for Forest Management

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Property details

Acres: 100

Size: 0

Ownership: State

We are designing a timber sale on a state forest where the existing main access road has multiple failed culverts for streams that drain into the Deerfield River. The goal is to remove the failed culverts and replace them with an economical bridge alternative that will meet state and local environmental regulations while also taking into account increased water flows due to climate change. Additionally, the impacts of climate change to the forest in the riparian zone have been assessed and adaptive tactics have been created.

Climate Adaptation Plan	Protecting Riparian Zones with a Focus on Stream Crossings for Forest Management
Project Details	<p>100 acres</p> <p>Size: 0</p> <p>State ownership</p> <p>We are designing a timber sale on a state forest where the existing main access road has multiple failed culverts for streams that drain into the Deerfield River. The goal is to remove the failed culverts and replace them with an economical bridge alternative that will meet state and local environmental regulations while also taking into account increased water flows due to climate change. Additionally, the impacts of climate change to the forest in the riparian zone have been assessed and adaptive tactics have created.</p>
Management area(s)	South River SF Riparian Zones
Regional Climate Change Impacts & Property-Level Considerations	<p>The following climate change impacts are regional expectations drawn from published resources. Under each regional climate change impact statement, property-level considerations describe how the general trend might be meaningful at the scale of the property.</p> <p>Temperatures in New England are projected to increase 3.5 to 8.5 °F by the end of the century, with the greatest warming expected to occur during winter.</p> <p>Property considerations: High temperatures in the summer will potentially create drought conditions which will result in hydrophobic soil conditions. Reduced snow pack and lack of frost layer can cause root damage for shallow rooted species, such as sugar maple and hemlock. Both of these species are found in the forest.</p> <p>The growing season in New England and northern New York is generally expected to increase by 20 days or more by the end of the century, due to fewer days with a minimum temperatures below 32°F.</p> <p>Property considerations: This scenario will allow invasive plant species to spread throughout the understory. This may affect riparian buffer zone plant composition.</p> <p>The winter season will be shorter and milder across New England and northern New York, with less precipitation falling as snow and reduced snow cover and depth.</p> <p>Property considerations: This situation will result in increased stream flow during the winter months. Additionally, there will be increased runoff and decreased spring snow pack that recharges the water table.</p> <p>Precipitation patterns will be altered, with projected increases in annual precipitation and potential for reduced growing season precipitation in New England and northern New York.</p> <p>Property considerations: Severe summer droughts will create a stressed conditions for trees within the riparian buffer zone. In particular, sugar maple and hemlock are currently present and are also susceptible to drought.</p> <p>Intense precipitation events will continue to become more frequent in New England and northern New York.</p> <p>Property considerations: These "intense" precipitation events will increase scouring of the stream channel, have potential to exceed "bank full" conditions. If the failing culverts are left in place or are replaced with the same size, as Massachusetts law allows, this will continue to impair the natural flow of the stream.</p> <p>Warmer temperatures and altered precipitation in New England and northern New York will interact to change soil moisture patterns throughout the year, with the potential for both wetter and drier conditions depending on the location and season.</p> <p>Property considerations: The drier soil condition has potential to create a hydrophobic soil condition where there may be increased runoff. Where forested wetland "sources" exist (such as a seep) the drier condition may alter the function of the wetland. Wetter soil conditions may prevent forest management activities due to difficult accessibility to the stands.</p>

Forest vegetation in New England and northern New York may face increased risk of moisture deficit and drought during the growing season.

Property considerations: In particular, sugar maple and hemlock in the riparian buffer may be affected by drought. Additionally, understory species such as maiden hair fern and other rich mesic site species may be affected.

Certain insect pests and pathogens will increase in occurrence or become more damaging in New England and northern New York.

Property considerations: This stand is composed of ash and hemlock which are already at risk due to invasive insects. It is unknown if other invasive insects and diseases will infest the stands.

Many invasive plants will increase in extent or abundance in New England and northern New York.

Property considerations: Invasive plants are present in the stand and have potential to affect the riparian buffer zone species composition and function.

Many northern and boreal tree species will face increasing stress across much of New England and northern New York.

Property considerations: Species such as sugar maple, ash, yellow birch and red spruce are present and will be impacted.

Habitat will become more suitable in New England and northern New York for some southern species.

Property considerations: There is some red oak and bitternut hickory present within the stand. There is potential to increase the percentage of these species within the stand.

Forest composition will change across the landscape in New England and northern New York.

Property considerations: Northern and boreal species are present within the stand and over time will shift to the north. Other species that are more drought tolerant will reassemble within the gaps in the stand.

Shifts in forest composition in New England and northern New York will take at least several decades to occur in the absence of major disturbance.

Property considerations: Forest management activities are the "planned disturbances" and are making an effort to adapt the stands to climate change through shifting species composition to more drought tolerant species.

Conditions affecting tree regeneration and recruitment will change in New England and northern New York.

Property considerations: There is moderate mortality to seedlings and saplings of the existing species composition during severe drought. The more drought tolerant species will survive during these drought periods.

Forest productivity in New England and northern New York will increase during the next several decades in the absence of significant stressors.

Property considerations: If "forest productivity" means a healthier, faster growing forest; this may imply that the forested riparian buffer is more "stable" and functional.

Low-diversity systems are at greater risk from climate change.

Property considerations: There is a sugar maple stand with a high percentage of this species. Natural Heritage program will not allow harvesting within the stand and therefore natural processes will occur.

Species in fragmented landscapes will have less opportunity to migrate in response to climate change.

Property considerations: The South River State Forest is part of a large forested block with very little fragmentation.

Systems that are limited to particular environments will have less opportunity to migrate in response to climate change.

Property considerations: The "system" present, a rich mesic northern forest type, is at risk.

Systems that are more tolerant of disturbance have less risk of declining on the landscape

Property considerations: The "systems" that are more drought tolerant may replace the vulnerable existing rich mesic northern forest.



Climate Adaptation Plan for Individual Management areas

The following plan details the management goals and objectives for a particular component of the project. Included below is a detailed review of potential climate impacts and site level considerations, along with an evaluation of objectives, potential adaptation responses (tactics) and monitoring variables to assess success over time.

Plan for specific Management area	<p>South River SF Riparian Zones</p> <p>The riparian zones within the South River State Forest sourced by multiple seeps and small wetland areas. The soils are of the rich mesic type and are highly erodible. Stable stream crossings are essential to the forest management of the area.</p>
Management Goal	Replace failed culverts with an economical bridge alternative.
Management Objective(s)	Design a bridge option that would be accepted by local conservation commission under a RFD. <i>(3-4 months)</i>
Management Goal	Restore vertebrate and invertebrate passage in the riparian zone.
Management Objective(s)	<p>Replicate natural stream bottom conditions. <i>(7-8 months)</i></p> <p>increase length of natural stream bottom conditions that is continuous from the source to the river. <i>(7-8 months)</i></p>
Management Goal	Protect multiple riparian zones during forest management activities.
Management Objective(s)	<p>Control native and non native invasive plants in order to ensure tree regeneration and an understory dominated by native herbaceous and woody plants. <i>(In the next 2 years)</i></p> <p>Manage for diversity of tree species and age classes within the riparian zone, while maintaining adequate shade to control micro climate conditions and cooler water temperatures. <i>(In the next 2 years)</i></p> <p>Maintain soil moisture in this rich mesic ecosystem. <i>(In the next 2 years)</i></p> <p>Maintain at least 50% of the basal area in the riparian zone. <i>(In the next 2 years)</i></p>
Potential identified impacts for South River SF Riparian Zones	<p>Increased rainfall events will accelerate stream bed erosion</p> <p>Erosion has already occurred and existing culverts are no longer functional. This erosion is also impacted approaches on the forest roads.</p> <p>Regional climate change projections of streamflow characteristics in the Northeast and Midwest U.S. (http://www.sciencedirect.com/science/article/pii/S2214581815001226)</p> <p>Climate change will extend the growing season.</p> <p>The extended growing season will allow native and non-native invasives, such as bittersweet and grape to be more prolific. These species are present in the riparian buffer zone and have the ability to severely damage tree crowns Early and warmer spring scenario could lead to loss of cold hardiness, early leaf out and susceptibility to frost damage both in the crown and to the cambium.</p> <p>Climate Change Indicators: Length of Growing Season (https://www.epa.gov/climate-indicators/climate-change-indicators-length-growing-season)</p> <p>The interaction between freezing tolerance and phenology in temperate deciduous trees (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4192447/)</p>

	<p>Decreased snow pack, increased winter rainfall and potential summer drought could reduce the function of the wetland source of the streams. The streams in South River State Forest have small wetland sources where the function could be compromised by altered water availability.</p> <p>Climate Change Effects and Adaptation Approaches for Terrestrial Ecosystems, Habitats, and Species (http://www.nwf.org/~media/PDFs/Global-Warming/2014/Terrestrial-Report/CC-and-Terrestrial-Systems_Final-Report_NPLCC-NWF_online-size.pdf)</p> <p>Increased stress on trees in the riparian buffer. The riparian buffer is composed of primarily sugar maple, hemlock and white ash. All three species are sensitive to changes in water availability. Decreases in water availability causes stress that may increase mortality caused by native and non native insects and diseases.</p> <p>Decreased snowpack could lead to increased acidification of soils. Sugar maple is a dominant species in the watershed and riparian zones of the South River State Forest. Sugar maple may decline over the next 100 years due to acidification of forest soils.</p> <p>Influence of experimental snow removal on root and canopy physiology of sugar maple trees in a northern hardwood forest (https://www.nrs.fs.fed.us/pubs/jrnl/2013/nrs_2013_comerford_001.pdf)</p>
<p>Potential impact of climate change on health and function of system</p> <p>Adaptive Capacity of system to climate change impacts or disturbances</p> <p>Vulnerability determination</p>	<p>Disruptive</p> <p>Moderate</p> <p>Moderate</p>

Evaluation of climate change impacts on goals and objectives

Climate change might make management objectives for this property harder or easier to achieve, presenting challenges and opportunities. This section also includes a simple rating and description for the feasibility of meeting management objectives under current management. This is a critical step to evaluate whether management objectives are robust, or whether any might need to be changed.

Management Goal	Replace failed culverts with an economical bridge alternative.
Management Objective	Design a bridge option that would be accepted by local conservation commission under a RFD. (3-4 months)
Challenges	The potential for higher rainfall during the operability period would limit the success of this project. This would be due to high flows, wet soil conditions and the potential for high erosion.
Opportunities	The present impacts of climate change indicate increasing rainfall and therefore is negatively impacting the stream crossings. The predicted impacts of climate change, such as high velocity stream flows, only support the proposal to improve the stream crossing structure.

Feasibility of meeting objectives after evaluation of climate impacts on system	Medium
Other Considerations	Comments: Under the current wetland regulations this may fall under more stringent permitting. Due to the projected impacts of climate change, a project of this nature would be improving the "resource".

Responding to climate change impacts

The following adaptation actions (tactics) were identified to help prepare for climate change impacts. Each adaptation tactic is linked to one or more Adaptation Strategies and Approaches, providing connections to climate change adaptation and forest management and conservation. Refer to the Adaptation Workbook for a complete list of Adaptation Strategies and Approaches.

Note - Tactics that are recommended can be implemented or explored further. However, some adaptation tactics might not be recommended for implementation on this property, which may be due to a combination of barriers and drawbacks or external factors.

Adaptation Tactic	Remove failing culverts. Replace them with bridges.
Strategy	Sustain fundamental ecological functions
Approach	Maintain or restore riparian areas
Benefits of this tactic	Replacing culverts with bridges will restore connectivity and protect stream channels.
Drawbacks and barriers of this tactic	none
Timeframe to implement	in the next year
Practicability	<i>An adaptation tactic is practicable if it is both effective & feasible to implement and to ultimately achieve desired intent.</i>
... practicability of tactic?	High
Recommendation for implementation	<i>The decision to recommend a tactic may be based on the likelihood of success, potential tradeoffs, cost, and other factors.</i>
... recommend tactic?	Yes

Monitoring adaptation actions

Monitoring is critical for understanding if management actions are effective or if management should be altered in the future to account for new information. The following monitoring variables were described for this particular management objective and adaptation tactics.

Monitoring variables used to evaluate if tactic is achieving desired	Bridge alternative is accepted by the local conservation commission. Culverts have been removed.
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<p>management objective(s)</p> <p>Monitoring Variable 1</p> <p>Threshold or Criteria for Evaluation of adaptation tactic</p> <p>Implementing monitoring efforts (frequency, time of year, etc)</p>	<p>Request for Determination or Limited Project permits were issued.</p> <p>Permits will be issued prior to the timber sale.</p>
<p>Monitoring variables used to evaluate if tactic is achieving desired management objective(s)</p> <p>Monitoring Variable 2</p> <p>Threshold or Criteria for Evaluation of adaptation tactic</p> <p>Implementing monitoring efforts (frequency, time of year, etc)</p>	<p>Bridge design and construction cost limitations.</p> <p>Costs don't exceed 40% of the income generated by the timber sale.</p> <p>Estimated costs will be gathered prior to the timber sale.</p>

Evaluation of climate change impacts on goals and objectives

Climate change might make management objectives for this property harder or easier to achieve, presenting challenges and opportunities. This section also includes a simple rating and description for the feasibility of meeting management objectives under current management. This is a critical step to evaluate whether management objectives are robust, or whether any might need to be changed.

Management Goal	Restore vertebrate and invertebrate passage in the riparian zone.
Management Objective	Replicate natural stream bottom conditions. <i>(7-8 months)</i>
Challenges	If summers and autumns are wetter, the feasibility of working to replicate the natural stream bottom would be limited.
Opportunities	If there are drought conditions, there would be a better chance of working in low or no flow conditions. This would improve the outcome of the job and would limit sedimentation.
Feasibility of meeting	Medium

objectives after evaluation of climate impacts on system	Comments: With the current climate conditions the window of opportunity to complete this job is unpredictable.
Other Considerations	Comments: Any work in the the stream bottom, bank or buffer zone requires permitting through the town's conservation commission. This is will require funding that may only be feasible through the timber sale contract.

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Adaptation Tactic	Remove failing culverts. Replace them with bridges.
Strategy	Sustain fundamental ecological functions
Approach	Maintain or restore riparian areas
Benefits of this tactic	Replacing culverts with bridges will restore connectivity and protect stream channels.
Drawbacks and barriers of this tactic	none
Timeframe to implement	in the next year
Practicability	<i>An adaptation tactic is practicable if it is both effective & feasible to implement and to ultimately achieve desired intent.</i>
... practicability of tactic?	High
Recommendation for implementation	<i>The decision to recommend a tactic may be based on the likelihood of success, potential tradeoffs, cost, and other factors.</i>
... recommend tactic?	Yes

Monitoring adaptation actions

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Monitoring variables used to evaluate if tactic is achieving desired	Bridge alternative is accepted by the local conservation commission. Culverts have been removed.
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<p>management objective(s)</p> <p>Monitoring Variable 1</p> <p>Threshold or Criteria for Evaluation of adaptation tactic</p> <p>Implementing monitoring efforts (frequency, time of year, etc)</p>	<p>Request for Determination or Limited Project permits were issued.</p> <p>Permits will be issued prior to the timber sale.</p>
<p>Monitoring variables used to evaluate if tactic is achieving desired management objective(s)</p> <p>Monitoring Variable 2</p> <p>Threshold or Criteria for Evaluation of adaptation tactic</p> <p>Implementing monitoring efforts (frequency, time of year, etc)</p>	<p>Bridge design and construction cost limitations.</p> <p>Costs don't exceed 40% of the income generated by the timber sale.</p> <p>Estimated costs will be gathered prior to the timber sale.</p>
<p>Monitoring variables used to evaluate if tactic is achieving desired management objective(s)</p> <p>Monitoring Variable 3</p> <p>Threshold or Criteria for Evaluation of adaptation tactic</p> <p>Implementing monitoring efforts (frequency, time of year, etc)</p>	<p>Post culvert removal stream bottom conditions are improved and length of stream courses are increased.</p> <p>Stream course conditions are uninterrupted by culverts. Length of uninterrupted stream course has increased.</p> <p>Measure stream course post culvert removal.</p>

Evaluation of climate change impacts on goals and objectives

Climate change might make management objectives for this property harder or easier to achieve, presenting challenges and opportunities. This section also includes a simple rating and description for the feasibility of meeting management objectives under current management. This is a critical step to evaluate whether management objectives are robust, or whether any might need to be changed.

Management Goal	Restore vertebrate and invertebrate passage in the riparian zone.
Management Objective	increase length of natural stream bottom conditions that is continuous from the source to the river. (7-8 months)
Challenges	If the operability period is shortened due to wetter soils in both winter and in the growing period, more temporary stream crossings may be necessary.
Opportunities	In drought conditions, operability will allow equipment on a wider range of soils without impact, minimizing the number of temporary stream crossings
Feasibility of meeting objectives after evaluation of climate impacts on system	Medium Comments: The climate and weather conditions are already providing windows of dry or drought conditions for optimizing operability. The largest impediment to movement for wildlife are the existing failed culverts

Responding to climate change impacts

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Note - Tactics that are recommended can be implemented or explored further. However, some adaptation tactics might not be recommended for implementation on this property, which may be due to a combination of barriers and drawbacks or external factors.

Adaptation Tactic	Remove failing culverts. Replace them with bridges.
Strategy	Sustain fundamental ecological functions
Approach	Maintain or restore riparian areas
Benefits of this tactic	Replacing culverts with bridges will restore connectivity and protect stream channels.
Drawbacks and barriers of this tactic	none
Timeframe to implement	in the next year
Practicability	<i>An adaptation tactic is practicable if it is both effective & feasible to implement and to ultimately achieve desired intent.</i>
... practicability of tactic?	High
Recommendation for	<i>The decision to recommend a tactic may be based on the likelihood of success, potential</i>

implementation	<i>tradeoffs, cost, and other factors.</i>
... recommend tactic?	Yes

Monitoring adaptation actions

Monitoring is critical for understanding if management actions are effective or if management should be altered in the future to account for new information. The following monitoring variables were described for this particular management objective and adaptation tactics.

<p>Monitoring variables used to evaluate if tactic is achieving desired management objective(s)</p> <p>Monitoring Variable 1</p> <p>Threshold or Criteria for Evaluation of adaptation tactic</p> <p>Implementing monitoring efforts (frequency, time of year, etc)</p>	<p>Bridge alternative is accepted by the local conservation commission. Culverts have been removed.</p> <p>Request for Determination or Limited Project permits were issued.</p> <p>Permits will be issued prior to the timber sale.</p>
<p>Monitoring variables used to evaluate if tactic is achieving desired management objective(s)</p> <p>Monitoring Variable 2</p> <p>Threshold or Criteria for Evaluation of adaptation tactic</p> <p>Implementing monitoring efforts (frequency, time of year, etc)</p>	<p>Bridge design and construction cost limitations.</p> <p>Costs don't exceed 40% of the income generated by the timber sale.</p> <p>Estimated costs will be gathered prior to the timber sale.</p>
<p>Monitoring variables used to evaluate if tactic is achieving desired</p>	<p>Ensure that the stream replication areas are stable and functioning.</p>

<p>management objective(s)</p> <p>Monitoring Variable 3</p> <p>Threshold or Criteria for Evaluation of adaptation tactic</p> <p>Implementing monitoring efforts (frequency, time of year, etc)</p>	<p>The replicated area functions similar to upstream and downstream conditions.</p> <p>These replication areas will be monitored within the first 6 months of replication and then yearly for the next five years.</p>
<p>Monitoring variables used to evaluate if tactic is achieving desired management objective(s)</p> <p>Monitoring Variable 4</p> <p>Threshold or Criteria for Evaluation of adaptation tactic</p> <p>Implementing monitoring efforts (frequency, time of year, etc)</p>	<p>Post culvert removal stream bottom conditions are improved and length of stream courses are increased.</p> <p>Stream course conditions are uninterrupted by culverts. Length of uninterrupted stream course has increased.</p> <p>Measure stream course post culvert removal.</p>

Evaluation of climate change impacts on goals and objectives

Climate change might make management objectives for this property harder or easier to achieve, presenting challenges and opportunities. This section also includes a simple rating and description for the feasibility of meeting management objectives under current management. This is a critical step to evaluate whether management objectives are robust, or whether any might need to be changed.

Management Goal	Protect multiple riparian zones during forest management activities.
Management Objective	Control native and non native invasive plants in order to ensure tree regeneration and an understory dominated by native herbaceous and woody plants. <i>(In the next 2 years)</i>
Challenges	Longer growing periods due to warmer weather conditions will allow non native invasive plants to spread more rapidly. Wetter conditions both in the winter and summer may facilitate the spread of invasives.
Opportunities	none
Feasibility of meeting	Medium

objectives after
evaluation of climate
impacts on system

Responding to climate change impacts

The following adaptation actions (tactics) were identified to help prepare for climate change impacts. Each adaptation tactic is linked to one or more Adaptation Strategies and Approaches, providing connections to climate change adaptation and forest management and conservation. Refer to the Adaptation Workbook for a complete list of Adaptation Strategies and Approaches.

Note - Tactics that are recommended can be implemented or explored further. However, some adaptation tactics might not be recommended for implementation on this property, which may be due to a combination of barriers and drawbacks or external factors.

Adaptation Tactic	Invasive plants will be sprayed pre and post harvest.
Strategy	Reduce the impact of biological stressors
Approach	Manage herbivory to promote regeneration of desired species
Benefits of this tactic	This will encourage the growth of native plants.
Drawbacks and barriers of this tactic	none
Timeframe to implement	within a year
Practicability	<i>An adaptation tactic is practicable if it is both effective & feasible to implement and to ultimately achieve desired intent.</i>
... practicability of tactic?	High
Recommendation for implementation	<i>The decision to recommend a tactic may be based on the likelihood of success, potential tradeoffs, cost, and other factors.</i>
... recommend tactic?	Yes

Monitoring adaptation actions

Monitoring is critical for understanding if management actions are effective or if management should be altered in the future to account for new information. The following monitoring variables were described for this particular management objective and adaptation tactics.

Monitoring variables used to evaluate if tactic is achieving desired management objective(s)	Reduce the non native and native invasive plant species cover.
Monitoring Variable 1	

<p>Threshold or Criteria for Evaluation of adaptation tactic</p> <p>Implementing monitoring efforts (frequency, time of year, etc)</p>	<p>Reduce non native and native invasive plant species cover by 80% of existing infestation.</p> <p>The invasive cover will be measured initially post treatment and then a year later.</p>
<p>Monitoring variables used to evaluate if tactic is achieving desired management objective(s)</p> <p>Monitoring Variable 2</p> <p>Threshold or Criteria for Evaluation of adaptation tactic</p> <p>Implementing monitoring efforts (frequency, time of year, etc)</p>	<p>The variable is tree species composition and number age classes.</p> <p>Increase diversity within the riparian zone by three species. Introduce one new age class within the next ten years.</p> <p>Inventory riparian zones five and 10 years post harvest.</p>
<p>Monitoring variables used to evaluate if tactic is achieving desired management objective(s)</p> <p>Monitoring Variable 3</p> <p>Threshold or Criteria for Evaluation of adaptation tactic</p> <p>Implementing monitoring efforts (frequency, time of year, etc)</p>	<p>The rich mesic ecosystem plant communities that are currently present.</p> <p>The presence or absence of herbaceous plants that would be associated with the rich mesic community are measured.</p> <p>Inventory of the understory will be conducted five and ten years post harvest.</p>

Evaluation of climate change impacts on goals and objectives

Climate change might make management objectives for this property harder or easier to achieve, presenting challenges and opportunities. This section also includes a simple rating and description for the feasibility of meeting management objectives under current management. This is a critical step to evaluate whether management objectives are robust, or whether any might need to be changed.

Management Goal	Protect multiple riparian zones during forest management activities.
Management Objective	Manage for diversity of tree species and age classes within the riparian zone, while maintaining adequate shade to control micro climate conditions and cooler water temperatures. <i>(In the next 2 years)</i>
Challenges	Climate change will accelerate the spread of Hemlock woolly adelgid which will impact a major species in the riparian zone. Recent mortality to the hemlock stands is primarily due to elongate scale. We have very little biological information regarding this species. Both insects are present. Additionally, regeneration will become difficult due to invasive plants in the understory. White ash is also a significant component of the riparian zone and due to EAB it will need to be harvested. We are also experiencing in the area 5 new fungi causing needle cast on white pine.
Opportunities	<p>Due to the need for a more intense harvest of the riparian zone (due to exotic pests, see above), regeneration will be accelerated. This will occur in the near future while the climate is cooler.</p> <p>Climate change may facilitate the use of artificial regeneration to shift the composition in the riparian zone. Species such as Northern red oak and various species of hickory would be used. There is also an American chestnut seed orchard located on the forest and this would also be an excellent opportunity to re-introduce the species back to the landscape.</p>
Feasibility of meeting objectives after evaluation of climate impacts on system	<p>Medium</p> <p>Comments: the possibility of obtaining chestnut seedlings is high.</p>
Other Considerations	Comments: The current regulations require maintaining fifty percent of the basal area in the filter strips of streams.

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Note - Tactics that are recommended can be implemented or explored further. However, some adaptation tactics might not be recommended for implementation on this property, which may be due to a combination of barriers and drawbacks or external factors.

Adaptation Tactic	Invasive plants will be sprayed pre and post harvest.
Strategy	Reduce the impact of biological stressors
Approach	Manage herbivory to promote regeneration of desired species
Benefits of this tactic	This will encourage the growth of native plants.
Drawbacks and barriers of this tactic	none

Timeframe to implement	within a year
Practicability	<i>An adaptation tactic is practicable if it is both effective & feasible to implement and to ultimately achieve desired intent.</i>
... practicability of tactic?	High
Recommendation for implementation	<i>The decision to recommend a tactic may be based on the likelihood of success, potential tradeoffs, cost, and other factors.</i>
... recommend tactic?	Yes
Adaptation Tactic	Use of uneven aged silviculture will promote diverse age classes and species composition. The necessity to harvest hemlock and ash will be the first step towards establishment of a new cohort.
Strategy	Maintain and enhance species and structural diversity
Approach	Promote diverse age classes
Benefits of this tactic	Establishing multiple age classes will provide a long term approach to forest sustainability.
Drawbacks and barriers of this tactic	none
Timeframe to implement	In the next 2 years
Practicability	<i>An adaptation tactic is practicable if it is both effective & feasible to implement and to ultimately achieve desired intent.</i>
... practicability of tactic?	High
Recommendation for implementation	<i>The decision to recommend a tactic may be based on the likelihood of success, potential tradeoffs, cost, and other factors.</i>
... recommend tactic?	Yes
Adaptation Tactic	Maintain at least 50% of the basal area along streams, following the Massachusetts current regulations.
Strategy	Sustain fundamental ecological functions
Approach	Maintain or restore riparian areas
Benefits of this tactic	Maintain shade along the stream bed, while regenerating new age classes.
Drawbacks and barriers of this tactic	The current regulations limit removals of timber to 50% of the basal area. In situations where hemlock is in severe decline, the residual stand will have a high mortality rate.
Timeframe to implement	In the next 2 years

Practicability	<i>An adaptation tactic is practicable if it is both effective & feasible to implement and to ultimately achieve desired intent.</i>
... practicability of tactic?	High
Recommendation for implementation	<i>The decision to recommend a tactic may be based on the likelihood of success, potential tradeoffs, cost, and other factors.</i>
... recommend tactic?	Yes

Monitoring adaptation actions

Monitoring is critical for understanding if management actions are effective or if management should be altered in the future to account for new information. The following monitoring variables were described for this particular management objective and adaptation tactics.

Monitoring variables used to evaluate if tactic is achieving desired management objective(s)	Reduce the non native and native invasive plant species cover.
Monitoring Variable 1	
Threshold or Criteria for Evaluation of adaptation tactic	Reduce non native and native invasive plant species cover by 80% of existing infestation.
Implementing monitoring efforts (frequency, time of year, etc)	The invasive cover will be measured initially post treatment and then a year later.
Monitoring variables used to evaluate if tactic is achieving desired management objective(s)	The variable is tree species composition and number age classes.
Monitoring Variable 2	
Threshold or Criteria for Evaluation of adaptation tactic	Increase diversity within the riparian zone by three species. Introduce one new age class within the next ten years.
Implementing monitoring efforts	Inventory riparian zones five and 10 years post harvest.

(frequency, time of year, etc)	
Monitoring variables used to evaluate if tactic is achieving desired management objective(s)	The rich mesic ecosystem plant communities that are currently present.
Monitoring Variable 3	
Threshold or Criteria for Evaluation of adaptation tactic	The presence or absence of herbaceous plants that would be associated with the rich mesic community are measured.
Implementing monitoring efforts (frequency, time of year, etc)	Inventory of the understory will be conducted five and ten years post harvest.

Evaluation of climate change impacts on goals and objectives

Climate change might make management objectives for this property harder or easier to achieve, presenting challenges and opportunities. This section also includes a simple rating and description for the feasibility of meeting management objectives under current management. This is a critical step to evaluate whether management objectives are robust, or whether any might need to be changed.

Management Goal	Protect multiple riparian zones during forest management activities.
Management Objective	Maintain soil moisture in this rich mesic ecosystem. <i>(In the next 2 years)</i>
Challenges	The existing road system currently alters the flow of water both surface and subsurface. Placement of new skid trails and roads may be affected by wetter soils during operation.
Opportunities	Extreme dry periods may offer an opportunity to both repair or remove older skid roads and build more effective roads.
Feasibility of meeting objectives after evaluation of climate impacts on system	Medium Comments: It is difficult to say that soil moisture can be controlled. However, depending on weather conditions during the harvest operation opportunities may be captured.
Other Considerations	Comments: The feasibility to do road work is linked to timber sale revenue.

Responding to climate change impacts

The following adaptation actions (tactics) were identified to help prepare for climate change impacts. Each adaptation tactic is linked to one or more Adaptation Strategies and Approaches, providing connections to climate change adaptation and forest management and conservation. Refer to the Adaptation Workbook for a complete list of Adaptation Strategies and Approaches.

Note - Tactics that are recommended can be implemented or explored further. However, some adaptation tactics might not be recommended for implementation on this property, which may be due to a combination of barriers and drawbacks or external factors.

Adaptation Tactic	Remove failing culverts. Replace them with bridges.
Strategy	Sustain fundamental ecological functions
Approach	Maintain or restore riparian areas
Benefits of this tactic	Replacing culverts with bridges will restore connectivity and protect stream channels.
Drawbacks and barriers of this tactic	none
Timeframe to implement	in the next year
Practicability	<i>An adaptation tactic is practicable if it is both effective & feasible to implement and to ultimately achieve desired intent.</i>
... practicability of tactic?	High
Recommendation for implementation	<i>The decision to recommend a tactic may be based on the likelihood of success, potential tradeoffs, cost, and other factors.</i>
... recommend tactic?	Yes
Adaptation Tactic	Use of uneven aged silviculture will promote diverse age classes and species composition. The necessity to harvest hemlock and ash will be the first step towards establishment of a new cohort.
Strategy	Maintain and enhance species and structural diversity
Approach	Promote diverse age classes
Benefits of this tactic	Establishing multiple age classes will provide a long term approach to forest sustainability.
Drawbacks and barriers of this tactic	none
Timeframe to implement	In the next 2 years
Practicability	<i>An adaptation tactic is practicable if it is both effective & feasible to implement and to ultimately achieve desired intent.</i>
... practicability of tactic?	High
Recommendation for implementation	<i>The decision to recommend a tactic may be based on the likelihood of success, potential tradeoffs, cost, and other factors.</i>
... recommend tactic?	Yes

Adaptation Tactic	Maintain at least 50% of the basal area along streams, following the Massachusetts current regulations.
Strategy	Sustain fundamental ecological functions
Approach	Maintain or restore riparian areas
Benefits of this tactic	Maintain shade along the stream bed, while regenerating new age classes.
Drawbacks and barriers of this tactic	The current regulations limit removals of timber to 50% of the basal area. In situations where hemlock is in severe decline, the residual stand will have a high mortality rate.
Timeframe to implement	In the next 2 years
Practicability	<i>An adaptation tactic is practicable if it is both effective & feasible to implement and to ultimately achieve desired intent.</i>
... practicability of tactic?	High
Recommendation for implementation	<i>The decision to recommend a tactic may be based on the likelihood of success, potential tradeoffs, cost, and other factors.</i>
... recommend tactic?	Yes

Monitoring adaptation actions

Monitoring is critical for understanding if management actions are effective or if management should be altered in the future to account for new information. The following monitoring variables were described for this particular management objective and adaptation tactics.

Monitoring variables used to evaluate if tactic is achieving desired management objective(s)	Reduce the non native and native invasive plant species cover.
Monitoring Variable 1	
Threshold or Criteria for Evaluation of adaptation tactic	Reduce non native and native invasive plant species cover by 80% of existing infestation.
Implementing monitoring efforts (frequency, time of year, etc)	The invasive cover will be measured initially post treatment and then a year later.
Monitoring variables used to evaluate if tactic	The variable is tree species composition and number age classes.

<p>is achieving desired management objective(s)</p> <p>Monitoring Variable 2</p> <p>Threshold or Criteria for Evaluation of adaptation tactic</p> <p>Implementing monitoring efforts (frequency, time of year, etc)</p>	<p>Increase diversity within the riparian zone by three species. Introduce one new age class within the next ten years.</p> <p>Inventory riparian zones five and 10 years post harvest.</p>
<p>Monitoring variables used to evaluate if tactic is achieving desired management objective(s)</p> <p>Monitoring Variable 3</p> <p>Threshold or Criteria for Evaluation of adaptation tactic</p> <p>Implementing monitoring efforts (frequency, time of year, etc)</p>	<p>The rich mesic ecosystem plant communities that are currently present.</p> <p>The presence or absence of herbaceous plants that would be associated with the rich mesic community are measured.</p> <p>Inventory of the understory will be conducted five and ten years post harvest.</p>

Evaluation of climate change impacts on goals and objectives

Climate change might make management objectives for this property harder or easier to achieve, presenting challenges and opportunities. This section also includes a simple rating and description for the feasibility of meeting management objectives under current management. This is a critical step to evaluate whether management objectives are robust, or whether any might need to be changed.

Management Goal	Protect multiple riparian zones during forest management activities.
Management Objective	Maintain at least 50% of the basal area in the riparian zone. <i>(In the next 2 years)</i>
Challenges	none
Opportunities	N/A
Feasibility of meeting objectives after	

Responding to climate change impacts

The following adaptation actions (tactics) were identified to help prepare for climate change impacts. Each adaptation tactic is linked to one or more Adaptation Strategies and Approaches, providing connections to climate change adaptation and forest management and conservation. Refer to the Adaptation Workbook for a complete list of Adaptation Strategies and Approaches.

Note - Tactics that are recommended can be implemented or explored further. However, some adaptation tactics might not be recommended for implementation on this property, which may be due to a combination of barriers and drawbacks or external factors.

Adaptation Tactic	Maintain at least 50% of the basal area along streams, following the Massachusetts current regulations.
Strategy	Sustain fundamental ecological functions
Approach	Maintain or restore riparian areas
Benefits of this tactic	Maintain shade along the stream bed, while regenerating new age classes.
Drawbacks and barriers of this tactic	The current regulations limit removals of timber to 50% of the basal area. In situations where hemlock is in severe decline, the residual stand will have a high mortality rate.
Timeframe to implement	In the next 2 years
Practicability	<i>An adaptation tactic is practicable if it is both effective & feasible to implement and to ultimately achieve desired intent.</i>
... practicability of tactic?	High
Recommendation for implementation	<i>The decision to recommend a tactic may be based on the likelihood of success, potential tradeoffs, cost, and other factors.</i>
... recommend tactic?	Yes

References

- L. Joyce, S. Running, and others. 2014. National Climate Assessment - Forestry. <http://nca2014.globalchange.gov/report/sectors/forests>.
- New England Climate Change Response Framework. <http://forestadaptation.org/new-england>.
- C. Zganjar, E. Girvetz, and others. 2009. Climate Wizard. <http://www.climatewizard.org/>.
- Adaptation Subcommittee to the Governor's Steering Committee on Climate Change. 2010. The impacts of climate change on Connecticut agriculture, infrastructure, natural resources, and public health.. <http://www.ct.gov/deep/lib/deep/climatechange/impactsofclimatechange.pdf>.
- R. Sturrock, S. Frankel, and others. 2011. Climate change and forest diseases. *Plant Pathology*, 60(1):133-149. <http://onlinelibrary.wiley.com/doi/10.1111/j.1365-3059.2010.02406.x/full>.

Landscape Change Research Group. 2014. Climate Change Atlas. <http://www.fs.fed.us/nrs/atlas/>.

Galbraith, H. 2011. Report to the NEAFWA vulnerability assessment expert panel: exposure information. http://rcngrants.org/sites/default/files/final_reports/RCN%202009-01%20Final%20Report%20-%20Northeastern%20exposure%20data.pdf.

P. Frumhoff, J. McCarthy, and others. 2007. Confronting climate change in the U.S. Northeast: Science, impacts, and solutions. http://www.ucsusa.org/sites/default/files/legacy/assets/documents/global_warming/pdf/confronting-climate-change-in-the-u-s-northeast.pdf.

J. Hellman, J. Byers, and others. 2008. Five potential consequences of climate change for invasive species. *Conservation Biology*, 22(3):534-543. <http://onlinelibrary.wiley.com/doi/10.1111/j.1523-1739.2008.00951.x/full>.

M. Notaro, D. Lorenz, and others. 2014. 21st century projections of snowfall and winter severity across central-eastern North America. *Journal of Climate*, 27:6526–6550. <http://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-13-00520.1>.

New Hampshire Climate Change Policy Task Force. 2009. The New Hampshire climate action plan: a plan for New Hampshire's energy, environmental and economic development future. http://des.nh.gov/organization/divisions/air/tsb/tps/climate/action_plan/documents/nhcap_final.pdf.

G. Galford, A. Hoogenboom, and others. 2014. Considering Vermont's Future in a Changing Climate: The First Vermont Climate Assessment. . http://dev.vtclimate.org/wp-content/uploads/2014/04/VCA2014_FullReport.pdf.

J. Thompson, D. Foster, and others. 2011. The influence of land use and climate change on forest biomass and composition in Massachusetts, USA. *Ecological Applications*, 21(7):2425-2444. <http://onlinelibrary.wiley.com/doi/10.1890/10-2383.1/full>.

A. Georgakakos, P. Fleming, and others. 2014. National Climate Assessment – Water. <http://nca2014.globalchange.gov/report/sectors/water>.

L. Rustad, J. Campbell, and others. 2012. Changing climate, changing forests: Impacts of climate change on forests of the northeastern United States and eastern Canada. USDA Forest Service Northern Research Station, GTR-NRS-99:48 p. <http://www.treearch.fs.fed.us/pubs/41165>.

Rustad, L.; Campbell, J.; Dukes, J.S.; Huntington, T.; Fallon Lambert, K.; Mohan, J.; Rodenhouse, N. 2012. Changing climate, changing forests: The impacts of climate change on forests of the northeastern United States and eastern Canada. http://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs99.pdf.

G. Jacobson, I. Fernandez, and others. 2009. Maine's Climate Future: An Initial Assessment. http://climatechange.umaine.edu/files/Maines_Climate_Future.pdf.

M. Duveneck, J. Thompson, and others. 2016. Recovery dynamics and climate change effects to future New England forests. <http://link.springer.com/article/10.1007/s10980-016-0415-5>.

R. Bierbaum, A. Lee, and others. 2014. National Climate Assessment – Adaptation. <http://nca2014.globalchange.gov/report/response-strategies/adaptation>.

K. Hayhoe, C. Wake, and others. 2006. Past and future changes in climate and hydrological indicators in the US Northeast. *Climate Dynamics*, 28:381-407. <http://link.springer.com/article/10.1007/s00382-006-0187-8>.

Runkle, Jennifer. 2017. NOAA National Centers For Environmental Information, State Climate Summaries: Maine. ME-screen-hi.pdf. <https://statesummaries.ncics.org/me>. <https://adaptationworkbook.org/sites/default/files/resources/ME-screen-hi.pdf>.

K. Kunkel, L. Stevens, and others. 2013. Regional climate trends and scenarios for the U.S. National Climate Assessment: Northeast U.S. . http://www.nesdis.noaa.gov/technical_reports/NOAA_NESDIS_Tech_Report_142-1-Climature_of_the_Northeast_U.S.pdf.

W. Wang, H. He, and others. 2016. Changes in forest biomass and tree species distribution under climate change in the northeastern United States. <http://www.nrs.fs.fed.us/pubs/52485>.

R. Horton, G. Yohe, and others. 2014. National Climate Assessment – Northeast. <http://nca2014.globalchange.gov/report/regions/northeast>.

R. Horton, G. Yohe, and others. 2014. National Climate Assessment - Northeast. <http://nca2014.globalchange.gov/report/regions/northeast>.

Manomet Center for Conservation Sciences and National Wildlife Federation. 2012. The vulnerabilities of fish and wildlife in the Northeast to climate change. Climate Change and Riverine Cold Water Fish Habitat in the Northeast. The Vulnerabilities of Northeastern Fish and Wildlife Habitats to Sea Level Rise. <http://northatlanticlcc.org/projects/vulnerabilities-climate-change-northeast-fish-wildlife-habitats/document-the-vulnerabilities-of-northeastern-fish-and-wildlife-habitats-to-climate-change>.
<http://northatlanticlcc.org/projects/vulnerabilities-climate-change-northeast-fish-wildlife-habitats/final-report-climate-change-and-riverine-cold-water-fish-habitat-in-the-northeast-a-vulnerability-assessment-review>.
<http://northatlanticlcc.org/projects/vulnerabilities-climate-change-northeast-fish-wildlife-habitats/the-vulnerabilities-of-northeastern-fish-and-wildlife-habitats-to-sea-level-rise>.

N. Fisichelli, A. Wright, and others. 2014. First-year seedlings and climate change: species-specific responses of 15 North American tree species. *Oikos*, 123(11):1331-1340. <http://onlinelibrary.wiley.com/doi/10.1111/oik.01349/full>.

J. Walsh, D. Wuebbles, and others. 2014. National Climate Assessment - Our Changing Climate. <http://nca2014.globalchange.gov/report/our-changing-climate/introduction>.

2015. Creating and Maintaining Resilient Forests in Vermont: Adapting Forests to Climate Change. http://fpr.vermont.gov/sites/fpr/files/Forest_and_Forestry/The_Forest_Ecosystem/Library/Climate%20change%20report_final_v6-18-15a.pdf.

M. Abrams. 2003. Where has all the white oak gone?. *BioScience*, 53(10):927-939. <http://bioscience.oxfordjournals.org/content/53/10/927.short>.

C. Swanston, M. Janowiak, and others. 2016. Forest Adaptation Resources: Climate change tools and approaches for land managers, 2nd Edition. USDA Forest Service Northern Research Station, GTR-NRS-87-2:161 p. <http://www.nrs.fs.fed.us/pubs/52760>.

J. Vose, D. Peterson, and others. 2012. Effects of Climate Variability and Change on Forest Ecosystems: A Comprehensive Science Synthesis for the U.S. Forest Sector.. USDA Forest Service Pacific Northwest Research Station, PNW-GTR-870:265. http://www.usda.gov/oce/climate_change/effects_2012/effects_forest.htm.

L. Ning and R. Bradley. 2015. Snow occurrence changes over the central and eastern United States under future warming scenarios. *Scientific Reports*, 5:17073. <https://dx.doi.org/10.1038%2Fsrep17073>.

S. Ollinger, C. Goodale, and others. 2008. Potential effects of climate change and rising CO2 on ecosystem processes in northeastern U.S. forests. *Mitigation and Adaptation Strategies for Global Change*, 13(5):467-485. <http://link.springer.com/article/10.1007/s11027-007-9128-z>.

P. Groffman, P. Kareiva, and others. 2014. National Climate Assessment - Ecosystems. <http://nca2014.globalchange.gov/report/sectors/ecosystems>.

R. Kopp, R. Horton, and others. 2014. Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites. *Earth's Future*, 2:383-406. <http://onlinelibrary.wiley.com/doi/10.1002/2014EF000239/full>.

M. Janowiak, A. D'Amato, and others. New England and New York forest ecosystem vulnerability assessment and synthesis: a report from the New England Climate Change R. <http://www.forestadaptation.org/new-england/vulnerability-assessment>.

American Forest Foundation. MyLandPlan.org. <http://mylandplan.org/>.

P. Frumhoff, J. McCarthy, and others. *Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions*. Union of Concerned Scientists, 2007:146 p. http://www.ucsusa.org/global_warming/science_and_impacts/impacts/northeast-climate-impacts.html#.VL5Sc0fF-6V.

P. Groffman, L. Rustad, and others. 2012. Long-term integrated studies show complex and surprising effects of climate change in the northern hardwood forest. *BioScience*, 62(12):1056-1066. <http://www.nrs.fs.fed.us/pubs/46691>.

Adaptation Subcommittee to the Governor's Steering Committee on Climate Change. 2010. The impacts of climate change on Connecticut agriculture, infrastructure, natural resources, and public health.. <http://www.ct.gov/deep/lib/deep/climatechange/impactsofclimatechange.pdf>.

D. Lorenz and M. Notaro. 2014. LCC Statistical Downscaling. http://ccr.aos.wisc.edu/resources/data_scripts/LCC/.

C. Dreyer, Y. Bergeron, and others. 2009. Effects of climate on occurrence and size of large fires in a northern hardwood landscape. *Applied Vegetation Science*, 12:261–272. <http://onlinelibrary.wiley.com/doi/10.1111/j.1654-109X.2009.01035.x/full>.

A. Weed, M. Ayres, and others. 2013. Consequences of climate change for biotic disturbances in North American forests. *Ecological Monographs*, 83(4):441-470. <http://onlinelibrary.wiley.com/doi/10.1890/13-0160.1/full>.

T. Huntington, D. Richardson, and others. 2009. Climate and hydrological changes in the northeastern United States. *Canadian Journal of Forest Research*, 39:199-212. <http://www.nrcresearchpress.com/doi/abs/10.1139/x08-116>.

Anderson, M.G.; Clark, M.; Ferree, C.; Jospe, A.; Olivero Sheldon, A.; Weaver, K. 2013. Northeast habitat guides: A companion to the terrestrial and aquatic habitat maps. .

http://rcngrants.org/sites/default/files/news_files/Northeast%20Aquatic%20and%20Terrestrial%20Habitat%20Guide.pdf.